ANALYSIS OF PULMONARY FUNCTION TEST ON VARIOUS CATEGORIES OF BMI

DISSERTATION SUBMITTED FOR

M.D., [PHYSIOLOGY] DEGREE - BRANCH V

THE TAMILNADU DR. MGR MEDICAL UNIVERSITY,

CHENNAI – 600 032.

MAY - 2019

DEPARTMENT OF PHYSIOLOGY

TRICHY SRM MEDICAL COLLEGE HOSPITAL AND RESEARCH CENTRE

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CERTIFICATE

This Dissertation titled **"ANALYSIS OF PULMONARY FUNCTION TEST ON VARIOUS CATEGORIES OF BMI" i**s submitted to The Tamil Nadu Dr.M.G.R Medical University, Chennai, in partial fulfillment of regulations for the award of M.D. Degree in Physiology in the examinations to be held during May 2019.

This Dissertation is a record of fresh work done by the candidate, **DR.A.V.LAVANYA**., during the course of the study (2016-2019).

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The research proposal submitted by, **Dr..Lavanya. A.V,** I year PG , Department of Physiology, Chennai Medical College Hospital & Research Centre, was discussed and analyzed by the Institutional Ethics Committee of the CMCH&RC. The committee approved the research project subject to existing rules and regulations.

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ACKNOWLEDGEMENT

It is my honour and privilege to thank **Prof. Dr. NACHAL ANNAMALAI M.D.,**

Professor, Department of Physiology, my guide, who has been helping me and guiding me at every stage since the genesis of idea for this study. Her valuable suggestions and timely advice were of immense help to me throughout all phases of this study. She has always been a great moral support and encouragement throughout the conduct of the study and also during my postgraduate course. I owe my sincere thanks to her.

I express my deep sense of gratitude towards **Dr, Muhil, M. M.D.,** Associate Professor, Department of Physiology, Trichy SRM Medical College Hospital & Research Centre, for constant encouragement and timely advice with respect to this study of mine.

I thank **Dr. Rajajeyakumar, M.D.,** Assistant Professor, Department of Physiology, Trichy SRM Medical College Hospital & Research Centre, for always being a constant encouragement, motivation and advice. I also thank **Dr. Niranjana M.D.,** Assistant Professor, Department of Physiology, Trichy SRM Medical College Hospital & Research Centre for his timely suggestions to improve the scope of the study and for helping me solve technical difficulties at every phase of this study.I also thank **Dr.S.V.Ajantha** M.D., tutor , Department of physiology , for constant encouragement and timely help during my postgraduate period.

I extend my gratitude towards our tutors, **Mr. R. A. Suresh Balaji, M.Sc., Mrs. H. Petricia, M.Sc.,** for their support in completing this study.

I shall ever remain indebted to my parents, family and friends for their encouragement and constant support.

I express my sincere gratitude to our respected Dean **Dr. A. Jesudoss MS., DLO.,** Trichy SRM Medical College Hospital & Research Centre, Trichy for permitting me to conduct this study.

I thank **Dr. P. Thirumalaikolundhu Subramanian M.D.,** Vice Principal, Trichy SRM Medical College Hospital & Research Centre, Trichy for his encouragement and suggestion in completing this study.

I express my heartfelt thanks towards the lab technicians and non-teaching fraternity of our department, who have been a significant support throughout my course.

Last but not least, I would grossly fail in my duty, if I do not thank my subjects who have undergone the inconvenience and discomfort of the investigations during this study.

DECLARATION

I.**Dr.A.V.LAVANYA** hereby solemnly declare that the dissertation entitled **"ANALYSIS OF PULMONARY FUNCTION TEST ON VARIOUS CATEGORIES OF BMI"** was done by me at Trichy SRM Medical College Hospital And Research Centre, Irungalur, Trichy, under the supervision and guidance of DR.NACHAL ANNAMALAI. M.D. (PHY), Professor and Head of the Department of Physiology, Trichy SRM Medical College Hospital And Research Center , Irungalur , Trichy.

This dissertation is submitted to TheTamilnadu Dr.M.G.R Medical University, towards partial fulfillment required for the award of M.D . Degree (Branch-V) in Physiology.

I have not submitted this dissertation on any previous occasion to any university for the award of any degree.

Place:

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Dr.A.V.LAVANYA

CERTIFICATE

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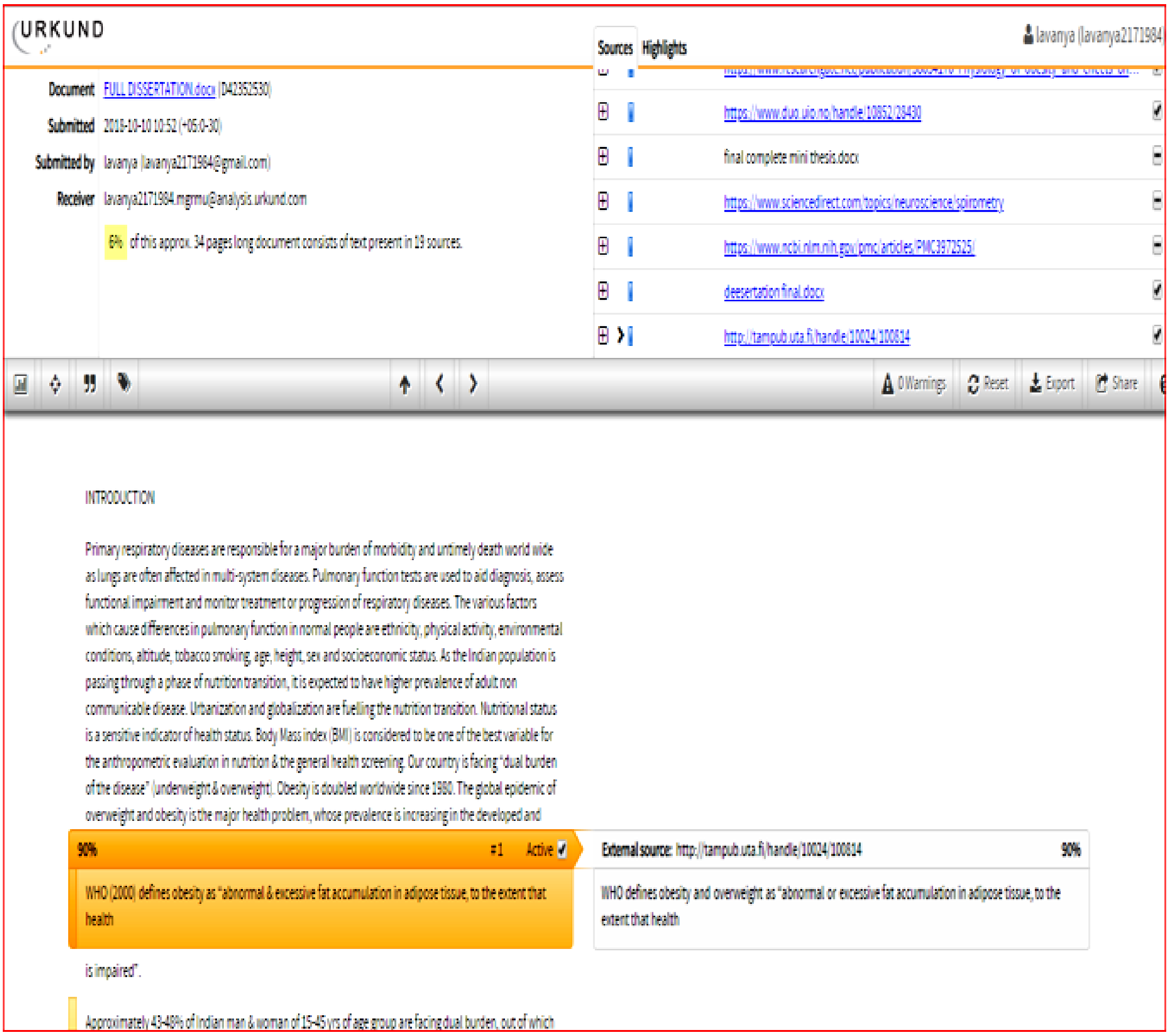

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LIST OF ABBREVIATIONS

WC	:	Waist Circumference
HC	:	Hip Circumference
WHR	:	Waist Hip Ratio
BMI	:	Body Mass Index
ATS	:	American Thoracic Society
ERS	:	European Respiratory Society
PFT	:	Pulmonary Function Test
TV	:	Tidal Volume
IRV	:	Inspiratory Reserve Volume
ERV	:	Expiratory Reserve Volume
RV	:	Residual Volume
VC	:	Vital Capacity
FVC	:	Forced Vital Capacity
IC	:	Inspiratory Capacity
FRC	:	Functional Residual Volume
TLC	:	Total Lung Volume
MVV	:	Maximum Voluntary Ventilation
PEF	:	Peak Expiratory Flow
MFVC	:	Maximum Expiratory Flow Volume Curve
FEV1	:	Forced Expiratory Volume At First Second
FEF	:	Forced Expiratory Flow
Paw	:	Airway Pressure
Ppl	:	Intrapulmonary Pressure

Patm	:	Atmospheric Pressure
LLN	:	Lower Limit Of Normal
GLI	:	Global Lung Initiation
GOLD	:	Global Initiative For Chronic Obstructive Lung Disease
NHANES	:	National Health And Nutrition Examination Survey
DLCO	:	Diffusing Capacity For Carbon Monoxide
PV	:	Pulmonary Vasculature
CW	:	Chest Wall
NM	:	Neuromuscular
ILD	:	Interstitial Lung Disease
CB	:	Chronic Bronchitis
COPD	:	Chronic Obstructive Lung Disease
ROS	:	Reactive Oxygen Species
EELV	:	End Expiratory Lung Volume
WOB	:	Work Of Breathing
EFL	:	Expiratory Flow Limitations
PEEPi	:	Intrinsic Positive End Expiratory Pressure
VE	:	Minute Ventilation
TI	:	Inspiratory Time
TE	:	Expiratory Time
TTOT	:	Total Time Of Respiratory Cycle
PI	:	Inspiratory Pressure
PImax	:	Maximal Inspiratory Pressure
MEP	:	Maximum Expiratory Pressure
MIP	:	Maximum Inspiratory Pressure

OSA	:	Obstructive Sleep Apnea
OHA	:	Obesity Hypoventilation Syndrome
ARDS	:	Acute Respiratory Distress Syndrome
SVC	:	Slow Vital Capacity
fR	:	Breathing Frequency

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INTRODUCTION

Primary respiratory diseases are responsible for a major burden of morbidity and untimely death world wide as lungs are often affected in multi-system diseases. Pulmonary function tests are used to aid diagnosis, assess functional impairment and monitor treatment or progression of respiratory diseases. The various factors which cause differences in pulmonary function in normal people are ethnicity, physical activity, environmental conditions, altitude, tobacco smoking, age, height, sex and socioeconomic status.[1]

As the Indian population is passing through a phase of nutrition transition, it is expected to have higher prevalence of adult non communicable disease. Urbanization and globalization are fuelling the nutrition transition. Nutritional status is a sensitive indicator of health status. Body Mass index (BMI) is considered to be one of the best variable for the anthropometric evaluation in nutrition & the general health screening.[2]

Our country is facing “dual burden of the disease” (underweight & overweight). Obesity is doubled worldwide since 1980.[3] The global epidemic of overweight and obesity is the major health problem, whose prevalence is increasing in the developed and developing countries .It is mainly due to an imbalance between calorie consumed & calorie expended[4]. **WHO (2000)** defines obesity as “abnormal & excessive fat accumulation in adipose tissue, to the extent that health is impaired”.[5]

Approximately 43-48% of Indian men & women of 15-45 yrs of age group are facing dual burden, out of which 30-36% people are underweight & 9-13% people are overweight according to 2005 national family health survey (NFHS-3)[6]. There are an estimated 1.8 billion adolescents in the world, in which 90% are residing in low- and middle-income countries These adolescents belonging to 10–19 year olds, form the largest generation of young people in our history.[6] According to National Family Health Survey (2006) data, 12.1% males & 16% females of Indian population are obese / overweight.[4]

Globally the prevalence of underweight is falling while the prevalence of overweight is rising. High body mass index (BMI) is the sixth most important risk factor contributing to the global disease burden according to the 2010 global burden of disease study[7]. It is the third risk factor for disease burden in countries of central Asia.[8]

The worldwide estimated prevalence of overweight and obesity increased from 937 & 397 million in 2005 to 1.35 billion & 573 million in 2030. 2.8 million people die as a result of being overweight & obese. In the age group of 35 -45 yrs, 36.9 % & 7.8% of people are overweight & obese respectively in India, when compared to rest of the world.[9]

Overweight & obesity are associated with an increase burden of diabetes, hypertension, cardiovascular disease, cancers & premature mortality. It is also a risk factor for various respiratory diseases like Obstructive Sleep Apnea Syndrome, Asthma, COPD.[10] The influence of obesity on pulmonary function tests has been examined but the role of body fat distribution on PFT has received limited attention. Studies of patients with upper body obesity have severely compromised lung volumes than obese patients with lower body obesity.[11]

Obesity causes alteration in the respiratory mechanics, decreased respiratory muscle strength, decrease in pulmonary gas exchange, a lower control of breathing and limitation in the pulmonary function test.[2,12] Obesity was also found to have negative association with lung functions.[2]The decline in pulmonary function with weight gain was mainly due to decrease in respiratory muscle power because obesity limits the mobility of the thoraxic cage.[13]Both static & dynamic lung volume & capacities were found to be decreased by decreasing lung & chest wall compliance, which results in increase in airway resistance during expiration.

The most common abnormal Pulmonary function in obese individual was the reduction in the functional residual volume & expiratory reserve volume which is generally seen when the weight to height ratio is greater than 0.7.[10] This reduction in FRC in obese individual was found to be due to deposition of adipose tissue surrounding the rib cage, abdomen & in the visceral cavity. In order to maintain appropriate level of ventilation, the obese individual had to do more respiratory effort to overcome respiratory system elasticity.[14]

Underweight is not only common in rural but also in urban areas. It is common in developing countries & is a burning issue in our country.[8] The prevalence of underweight was highest in semi-urban areas (30.2% and 53.2% according to Indian and international criteria, respectively). According to the Indian criteria, the underweight prevalence was 14.1% and 9.8% , in the urban and highly urban areas but according to international criteria it was 27.1% and 19.2%.[15] Underweight is associated with more frequent co-morbidities such as osteoporosis and asthma.[8]

Underweight is mainly due to undernourishment which results in reduced respiratory muscle mass and because of this diaphragm contractility is reduced. In prolonged under nutrition, energy is utilized at the expense of muscle protein leading to respiratory & diaphragm muscle atrophy. Under nutrition can also reduce skeletal and respiratory muscle mass, which results in reduction in FVC and FEV in underweight people.[16]

Several studies were mentioned about the pulmonary functions test in obesity. Only fewer PFT studies were done on underweight & very few comparative studies of PFT were done in all 3 categories of BMI. So in this present study pulmonary functions are analyzed in the 3 categories of BMI- normal, underweight & overweight.

AIMS & OBJECTIVES OF THE STUDY

- To categories the subjects according to BMI.

- To evaluate pulmonary function test in each subjects.

- To correlate the effects of pulmonary functions with various categories of BMI

REVIEW OF LITERATURE:

Breathing is an essential function for survival and alterations in lung function can alter the quality of life and day to day activities. In order to maintain respiratory homeostasis, the respiratory system structures have to work in equilibrium so that the lungs should be ventilated and the gases should diffuse through the alveolar-capillary barrier.[17]

Pulmonary Function Test:

Pulmonary function tests are commonly used for evaluating respiratory status & treating persons with known pulmonary disease. It is also a part of routine health examination in respiratory , occupational, sport medicine, & in public health screening.[18]The most important pulmonary function is the uptake of oxygen from inspired air and giving up of carbondioxide in the expired air thereby it maintain the tension of oxygen & carbon dioxide of arterial blood within normal range.[19]

Spirometry is a physiological test which measures how much an individual can inhale & exhale a definite volume of air as function of time.[20] The spirometry assesses the integrated mechanical function of lung , chest wall & respiratory muscles, by assessing different aspects of pulmonary functions such as ventilation, perfusion and diffusion.[19] The most important function of pulmonary function test is to distinguish the 2 major groups of patho physiologic diseases such as obstructive pulmonary disease & restrictive pulmonary disease.[21]

Measurable pulmonary parameters are:

1. Tidal Volume(VT)
2. Inspiratory reserve volume(IRV)

3. Expiratory Reserve Volume(ERV)
4. Inspiratory Capacity(IC)
5. Vital Capacity(VC)
6. Forced Expiratory Volume In 1 Second(FEV_1)
7. Forced Vital Capacity(FVC)
8. Forced Expiratory Flow ($FEF_{25-75\%}$)

The above parameters are measured using spirometry.[22]

Non Measurable pulmonary parameters are:

1. Residual volume
2. Forced residual capacity
3. Total lung capacity is the volume and capacity that are not measured using spirometry.[22]

It can be determined by the following techniques.

- Nitrogen washout technique
- Helium dilution technique
- Body plethysmography
- Radioactive xenon method.[22]

In 1947, Tiffeneau and Pinelli transformed spirometric measurements to the present form, in which the forced expiratory volume in 1 second (FEV_1) and the inspiratory or forced expiratory VC (IVC and FVC) became main diagnostic indices in clinical medicine.[23] The norms for the standardization of spirometric techniques were created by the committee members of the American Thoraxic Society after the snowbird workshop held in the year 1979, which was then updated in 1987 & in 2001.[20]

In 1994 there was an another similar initiative on the “Standardization of Spirometry” done by the European community for steal & coal which lead to formation of first ERS, which was updated in 1993. ERS included absolute lung volume, which was not included in ATS.[20] Now a days this physiological test is used as a screening test to rule out general respiratory illness.[20]

Indications are

- To evaluate the baseline lung function & dyspneia,
- To detect & to evaluate pulmonary impairment & disease ,
- To monitor effects of therapies used ,
- To evaluate operative risk & occupational-related lung disease.[24]

Contraindications are

- Hemoptysis of unknown origin,
- Peumothorax,
- Active tuberculosis,
- Unstable angina pectoris,
- Recent myocardial infarction,
- Thoraxic ,abdominal & cerebra aneurysms ,
- Recent eye surgery,
- Recent thoraxic & abdominal surgical procedures,
- H/o recent syncope.[24]

Factors affecting the lung functions:

Pulmonary functions are generally determined by

1. Airway resistance,
2. Compliance of the lung & thoracic cavity ,
3. Elastic recoil of the lung
4. Respiratory muscle strength.[25]

Spirometric lung function parameters can be affected by many sorts of variations such as

1) Technical variations which include instrument & procedural variations, observer bias, & individual variation & their interaction.
2) Biological variations which include intra-& inter –individual variations among populations
3) Clinical variations which include variations caused by dysfunction or disease .[18]

The most important determinant of inter individual variability in lung functions are

1) **Race or ethnic origin:**

   Whites (European descent) have slightly larger trunks and shorter legs compared to Blacks (African descent) at a given height which corresponds to vital capacities that are 10-15% larger for a given standing height in whites. Blacks, Hispanics and Native Americans have different PFT results compared to Caucasians. Ethnic differences in PFT have also been suggested for many other groups specifically Asians, Latin, Americans, Indians and South Africans.[26]

2) **Age**:

   As individual gets older, there will be reduction in the lung volumes and capacities[26]. According to Gomzi et al (1983) the pulmonary functions have been proved to be negatively correlated with age.[27]

3) **Gender**:

The volumes of adult female lung are 10-12% smaller than that of adult males who have the same range of height & age. In males, the pulmonary function test has a positive correlation with arm and leg length. In females, the pulmonary functions are negatively correlated with the body circumference, skin fold & the weight.[27]

According to study conducted by Joyarani etal (2015), females tend to have lower pulmonary function test value as their respiratory muscle endurance & chest wall compliance is lower than that of their male counterparts.[28] There is a stronger alterations in FVC and FEV1 in men when compared to women, because the males have a greater frequency of android fat deposit pattern, while females has gynoid fat. This greater deposit of fat in the abdominal region contributes to a greater resistance to diaphragmatic contraction which in turn alter the ventilatory mechanics according to the study conducted by Enzi et al (1916).[17]

4) **Height & weight**:

Mukhopadhvay et al states that shorter persons will have generally a smaller PFT results when compared to the taller persons of the same age.[26] Pulmonary function test has a highly positive correlation with height in sitting & standing posture in both sex.[27]

Weight has various effects on pulmonary function tests such as

1) Impairment on pulmonary function testing,
2) Small airway dysfunction and expiratory flow limitation,
3) Alterations in respiratory mechanics,
4) Decreased chest wall and lung compliance,

5) Decreased respiratory muscle strength and endurance,

6) Decreased pulmonary gas exchange,

7) Lower control of breathing,

8) Limitations in exercise capacity.[26,29]

5) **Socio-economic status**

Low socio-economic status individual do not have lung volumes & capacities like that of high socio-economic .There is a decline in respiratory functions earlier & rapidly in low socio-economic status when compared with high socioeconomic status.[27]

Pulmonary Function test parameters:

Ventilation is the process of air movement in & out of alveoli, which depends on 3 parameters like lung volume, capacities & mechanism of breathing[19].

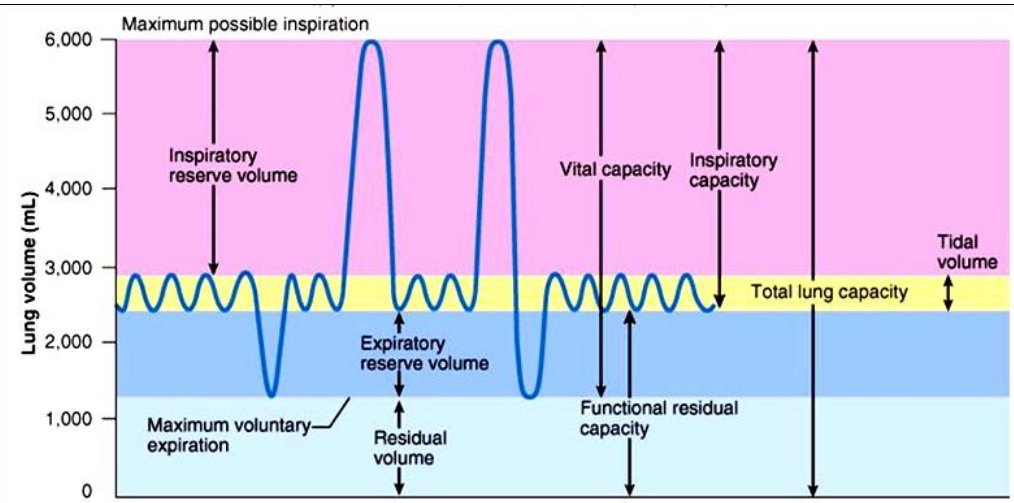


Figure-1 .lung volumes & capacities

Figure -1 shows the following lung volumes and capacities.

I. Lung Volumes :

1) **Tidal Volume (VT)**: The volume of air inspired or expired out of the lung during quiet breathing is the tidal volume.

   Normal value: 500ml in adult.

2) **Inspiratory Reserve Volume (IRV):** The volume of air inspired with maximal inspiratory effort in excess of the tidal volume (i.e) inspiratory muscle is used maximally while measuring IRV.

   Normal value: 3 1itre in male & 2 1itre in female.

3) **Expiratory Reserve Volume (ERV)**: The volume of air expired with a maximum expiratory effort after passive expiration is called ERV.

   Normal value: 1 liter in male & 0.7 liter in female.

4) **Residual Volume (RV):** The volume of air remains in the lung at the end of maximum expiratory effort.

   Normal value: 1.2 liter in male & 1.1 liter in female.[19]

2. Lung Capacities :

1) **Vital Capacity (VC):** The maximum amount of air expired after a maximum inspiratory effort. The measurement of vital capacity can also be considered as frequently used method in modern anthropological investigation & serve as a good indicator for assessing the living condition, abilities, physical &health condition of individuals & population.

   Normal value: 4.5 liter in male & 3 liter in female.

2) **Forced Vital Capacity (FVC):** The total volume of air expired forcefully and rapidly after maximum inspiration is the forced vital capacity. Any reduction of FVC in absence

of a reduced $FEV_1$to FVC ratio suggests a restrictive ventilatory problem. Severity of reduction in FVC can be characterized by

i. **Mild:**>70% of predicted
ii. **Moderate:**60-69% of predicted
iii. **Moderately severe:50-59%**
iv. **Severe:35-49% of predicted**
v. **Very severe:<35%predicted**[24]

3) **Inspiratory Capacity (IC):** Inspiratory capacity is the maximum amount of air that can be inspired from the resting expiratory level.

IC=IRV+TV

Normal value: 3.5 liter.

4) **Functional Residual Capacity (FRC):** The amount of air remaining in the lung at the end of normal expiration is the Functional Residual capacity.

FRC=ERV+RV.

Normal value: 2 liter.

5) **Total Lung Capacity (TLC):** Total lung capacity (TLC**)** is the volume of air present in the lung at the end of maximal inspiration.

Normal value: 6 liter in male, 4.2 liter in female.

4. **Mechanics of breathing** :

It depends upon the compliance & airway resistance. The compliance measures relative stiffness & distensibility of the lungs & thorax. Airway resistance is the resistances to airflow through the conducting air passages. Mechanics of breathing are assessed by the following parameters.[19]

1) **Maximum Mid expiratory Flow (MMEFR) or FEF$_{25-75}$:** The maximum flow achieved during middle third of the total expired volume is expressed as Forced Expiratory Flow (FEF) at 25-75% lung volume. FEF$_{25-75\%}$ indicates the patency of small airway. The measurement of flow rate FEF $_{200-1200ml}$ indicates the patency of large airway.[19]

2) **Maximum Voluntary Ventilation (MVV):** Maximum voluntary ventilation is the maximum volume of air that a subject can breathe rapidly and forcefully over a specified period of time .It is expressed in L/min.[20]

Normal value: 150 liter /min (males), 125 liter /min (females).

3) **Peak Expiratory Flow (PEF): PEF is** the maximum expiratory flow achieved from a maximum forced expiration, starting without hesitation from the point of maximum lung inflation, expressed in liter per second[20].It is used to assess large central airway obstruction.

   Normal value: 350-400 liter /min

4) **Maximal Expiratory Flow Volume Curve (MFVC):** This is the curve obtained, when expiratory flow rate is plotted against lung volume. It is helpful in quality control and in detecting the presence of upper airway obstruction.[20]

5) **Timed vital capacity (tVC) or FEV1:** It is the fraction of vital capacity expired in specific time. It is also called as forced expiratory volume in the first second (FEV1).[19]

In 2014, Jeremy D et al was the first to formulate the algorithm “A stepwise approach to interpretation of pulmonary function tests” for the interpretation of pulmonary function test results.[30]

FVC Maneuver :

Forced vital capacity is the most important single pulmonary function test which is measured from TLC. FVC maneuver can be displayed in 2 different ways.

1. Spirogram display
2. Flow volume loop display.[21]

1).Spirogram display or (volume /time curve):

The traditional way of evaluating FVC maneuver is by using the graph that shows the volume change against time. The instantaneous airflow at any time on this plot can be estimated from the steepness (rate of change or slope) of volume change with time[21]. It provides 4 important results.

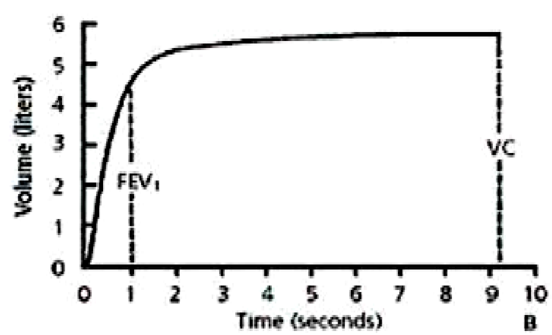


Figure-2.Spirogram display of FVC maneuver

(volume-time curve)

1. Forced vital capacity(FVC)
2. Forced expiratory volume in 1 second(FEV1)
3. Ratio of FEV1 TO FVC (FEV1/FVC)
4. Maximal Mid Expiratory Flow or FEF25-75(MMEF)[21.]

2).Flow volume loop:

The FVC maneuver can be displayed as flow volume loop in which the instantaneous flow rate is plotted against volume. It records instantaneous flow during both expiration (expiratory flow volume curve) and inspiration (inspiratory flow volume curve) .The subject is asked to perform normal tidal breathing, then the subject is asked to take maximum inspiration to TLC & exhale rapidly & forcefully until he can exhale maximum to RV.

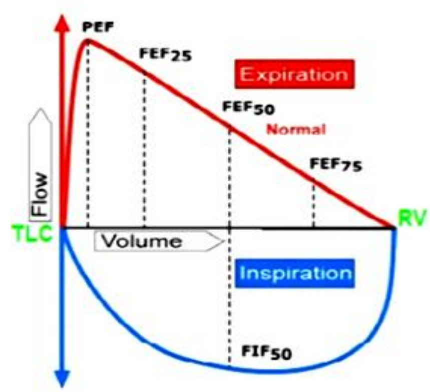


Figure-3.Flow Volume Loop display of FVC

Flow rate curve above horizontal line are expiratory and below the horizontal line are inspiratory. The point on the Flow volume loop at which maximum inspiration occurred is TLC & maximum exhalation occurred is RV.[21]

Expiratory Flow Volume Curve:

Expiratory Flow Volume Curve is divided into quarters .It gives 4 important result such as

1. **PEFR** is the greatest flow achieved during FVC maneuver.
2. The instantaneous flow rate at which 50 % of VC remains to be exhaled is called as **FEF_{50} or $V_{max\ 50}$.**
3. The flow rate at which 75 % of VC exhaled is called as **FEF_{75} or $V_{max\ 75}$.**
4. The flow rate at which 25 % of VC exhaled is called as **FEF_{25} or $Vmax_{25}$.**[21]

Type of Pulmonary defects :

The maximal flow volume curve is used as a diagnostic tool to distinguish 2 major classes of pulmonary diseases

(1).Obstructive disease are those disease that interfere with airflow

(2).Restrictive disease are those that restrict the expansion of the lung.[22]

(1). Obstructive pulmonary defect :

An obstructive ventilator defect is a disproportionate reduction in the maximal airflow from the lungs in relation to the lung volumes.[31] Asthma,bronchitis & emphysema are the some of the obstructive diseases which are associated with high lung volumes.[22] It is because this high lung volumes increases the alveolar elastic recoil pressures.[22] The most important feature of flow volume curve is the slowing in the terminal portion of the spirogram without affecting initial part of spirogram.It is the ealiest change of obstruction which is due to airflow obstruction in the smaller airways.This slowing of expiratory flow is reflected as concave shape in the effort independent portion of the flow volume loop.It reflects a greater reduction after 75% of VC is exhaled (FEF_{75}) or mean expiratory flow between 25% & 75% of FVC.[31]

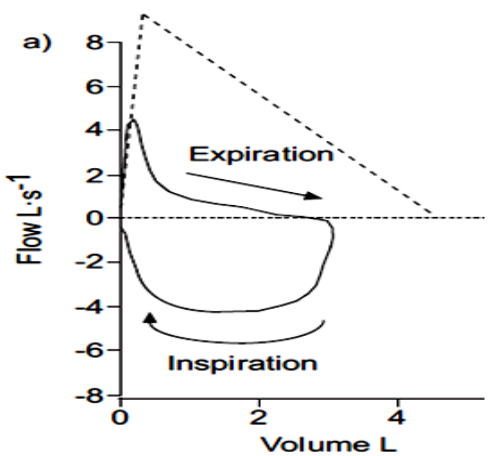


Figure -4.Flow Volume Loop of obstructive pulmonary defect

Figure 4 shows typical obstructive pulmonary defects with normal total lung capacity (TLC) 101% and reduced expiratory flow with FEV1 38%; FEV1/VC 46%; peak expiratory flow (PEF) 48%.In this obstructive pulmonary defect TLC remains normal & the flow are less than expected over the entire volume range.[31]

Obstructive pulmonary defect can be diagnosed based on the criteria:

1) $FEV_1/VC < 5^{th}$ percentile of predicted

2) A decrease in flow at low lung volume is not specific for small airway disease in individual patients.

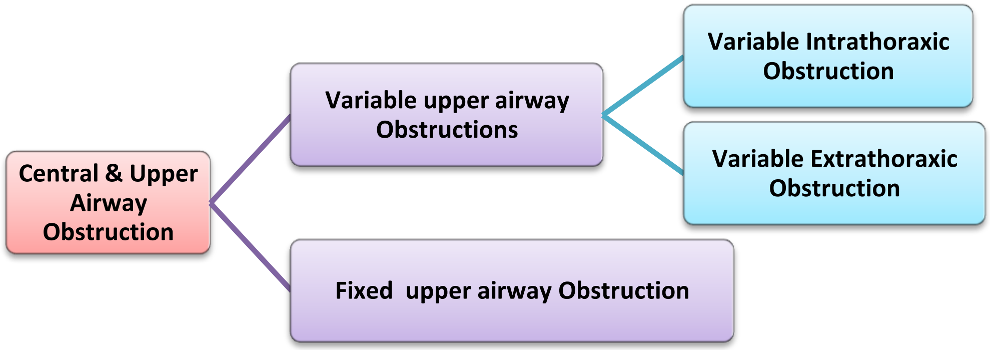
3) A concomitant disease in FEV_1 & VC is caused due to poor effort, but rarely reflects airflow obstruction. Measurement of lung volumes confirms the airway obstruction.

4) Measurement of absolute lung volumes assists in the diagnosis of emphysema, bronchial asthma & chronic bronchitis. It is also useful in assessing lung hyperinflation.

5) Measurement of airflow resistance is useful for patients who are not able to perform spirometric manoeuvres.[31]

Central and Upper Airway Obstruction :

Flow volume curves are useful in assessing obstruction of the upper airways & trachea.[22] The effect of Central and Upper Airway Obstruction on the Flow volume loop depends on whether the obstruction is within the thoracic cavity (intra thoracic) or outside the thoracic cavity (extra thoracic) and whether it is fixed or variable.[32] The central & upper airway obstructions occurs in both extra thoracic airway (pharynx, larynx and extra thoracic portion of the trachea) and intra thoracic airway (intra thoracic trachea & bronchi).[31] Depends upon the type & location of the pathology, there are 3 pattern of abnormalities in the flow volume loop.[32]



During forced inspiration, intra-airway pressure is lower than atmospheric pressure, and pleural pressure is lower than both airway & atmospheric pressure. But during forced expiration, intra-airway pressure is higher than atmospheric pressure, and pleural pressure is greater than both airway & atmospheric pressure.[32]

1). Fixed Upper Airway Obstruction :

Fixed Upper airway obstruction is seen in goiters, endotracheal neoplasm, stenosis of main bronchi and post intubation tracheal stenosis[24]. Fixed obstruction will limit both inspiratory & expiratory air flow[22], whether it is in chest or upper airway. Flow volume loop will appear similar in both cases.[32]

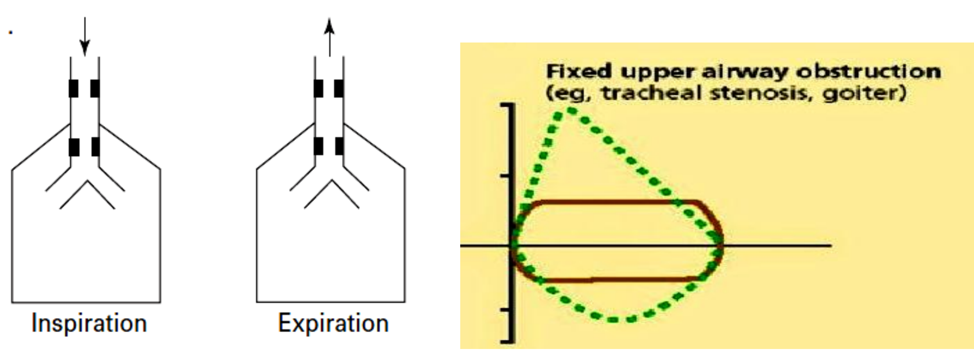


Figure -5. Fixed upper airway obstructions

Figure-5 shows the Fixed upper airway obstructions which demonstrates plateaus of air flow during both forced inspiration & forced expiration with reduced peak inspiratory & expiratory flow.

2) .Variable Upper Airway Obstruction :

Variable upper airway obstruction is seen in tracheomalacia. Flexible or floppy segments in trachea will either widen or narrow in response to the relative pressure difference between the airway lumen & surrounding tissue .This results in the generation of either variable intra thoraxic or extra thoraxic obstruction depending on the location of the obstruction[31].Variable upper airway obstructions causes changes in the cross sectional area of obstruction due to changes in the transmural pressure gradient caused by both inspiratory and expiratory effort.[22]

2 .(a).Variable Intra thoraxic Upper Airway Obstruction :

Variable intra thoraxic obstructions is seen in tumors of lower trachea & main bronchus, tracheomalacia & airway changes associated with polychrondritis.It shows the reduction of airflow during forced expirations with preservation of a normal inspiratory flow configuration. This expiratory airflow reduction is due to narrowing of the airway inside the thorax, secondary to extra luminal pressures exceeding intra luminal pressures during expiration.[24]

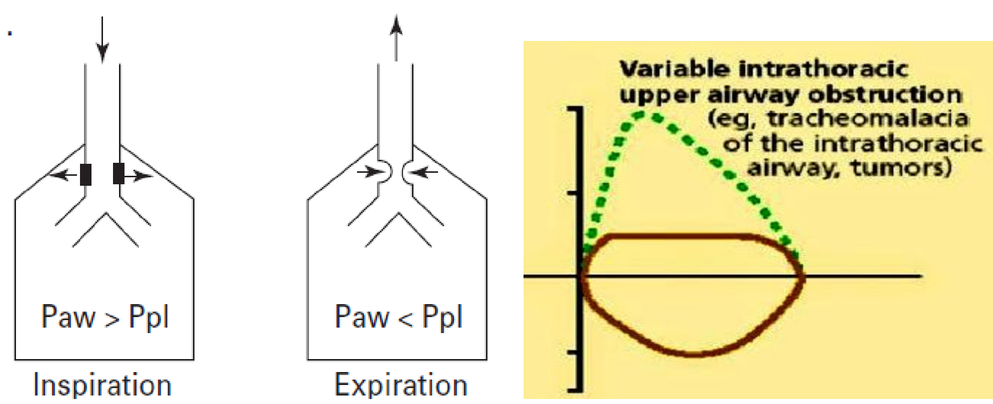


Figure -6 .Variable intra thoraxic upper airway obstructions

Figure-6 shows a variable intra thoraxic obstruction which demonstrates the plateau over the expiratory flow limb of the flow volume curve.[24]

2.(b).Variable Extra thoraxic Upper Airway Obstructions :

Variable extra thoraxic obstructions is seen in unilateral & bilateral vocal cord paralysis, vocal adhesion & constrictions, laryngeal edema and upper airway obstruction associated with sleep apnea .It demonstrate the reduction of inspired flow during forced inspirations with preservation of expiratory flow configuration. The major cause of the reduced flow during inspiration is airway narrowing, secondary to extra luminal pressures exceeding intra luminal pressures during inspiration.[24]

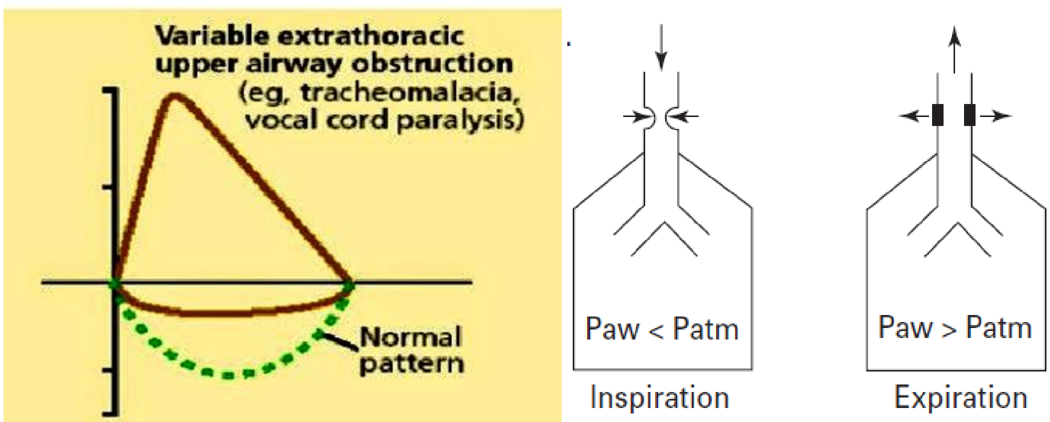


Figure -7 .Variable Extra thoraxic upper airway obstructions

Figure-7 shows the variable extra thoraxic obstruction which demonstrates the plateau over the inspiratory limb of the flow volume loop.[24]

(b). <u>Restrictive pulmonary defect</u> :

Restrictive pulmonary defect is characterized by reduction in FVC & TLC with normal or increased FEV1/FVC ratio. The expiratory flow shows a normal or convex shape in the effort independent portion of the flow volume loop.[31]

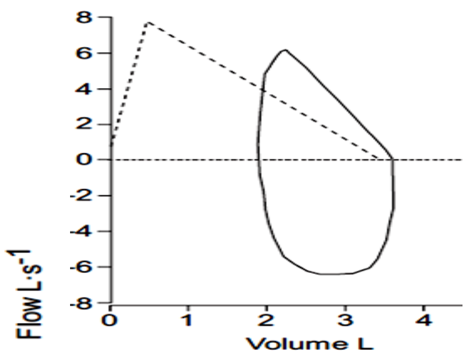


Figure-8. Flow Volume Loop of restrictive pulmonary defects

Figure-8 shows typical restrictive defect with reduced FEV1 66% and TLC 62%. The FEV1/VC remains increased with 80% and PEF 79%.In this restrictive pulmonary defect TLC is reduced and the flow is higher than expected at a given lung volume.[31]

Restrictive pulmonary defect can be diagnosed based on the criteria:

- TLC<5th percentile of predicted
- A reduced VC does not prove a restrictive pulmonary defect. It may be suggestive of lung restriction when FEV_1/VC is normal or increased.
- A low TLC from a single-breath test should not be seen as evidence of restriction.[31]

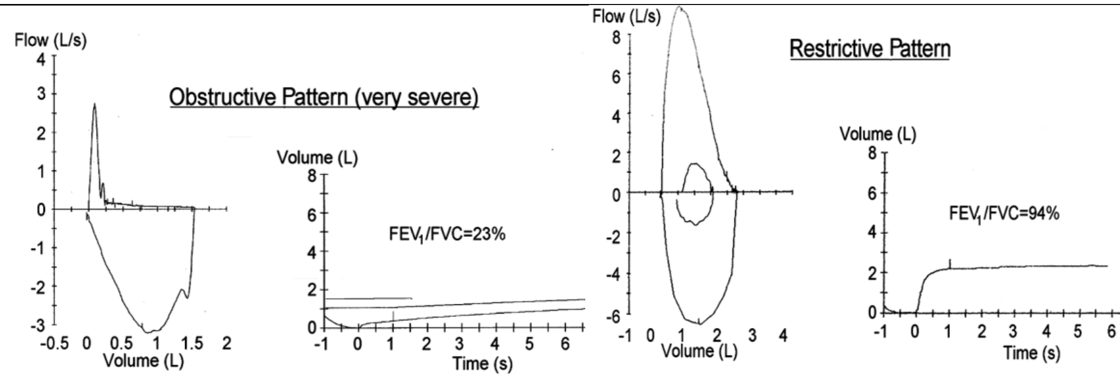


Figure-9.spirometry pattern of obstructive & restrictive lung disease.

Figure -9 shows the volume-time tracing of the patient with airways obstruction takes 19.5 seconds to expel out the entire vital capacity, whereas the patient with restrictive disease expels his entire vital capacity in little more than 1 second.[32]

(c).Mixed pulmonary defect:

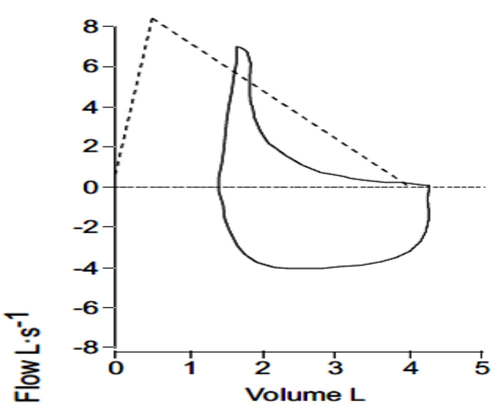


Figure-10. Flow Volume Loop of mixed pulmonary defect

Figure-10 shows typical mixed defect characterized by a low TLC (72%) and low FEV1/VC ratio (64%) with FEV1 64% & PEF 82%.[32]

Mixed pulmonary defect can be diagnosed when FEV_1/VC & TLC <5th percentile or predicted value.[32]

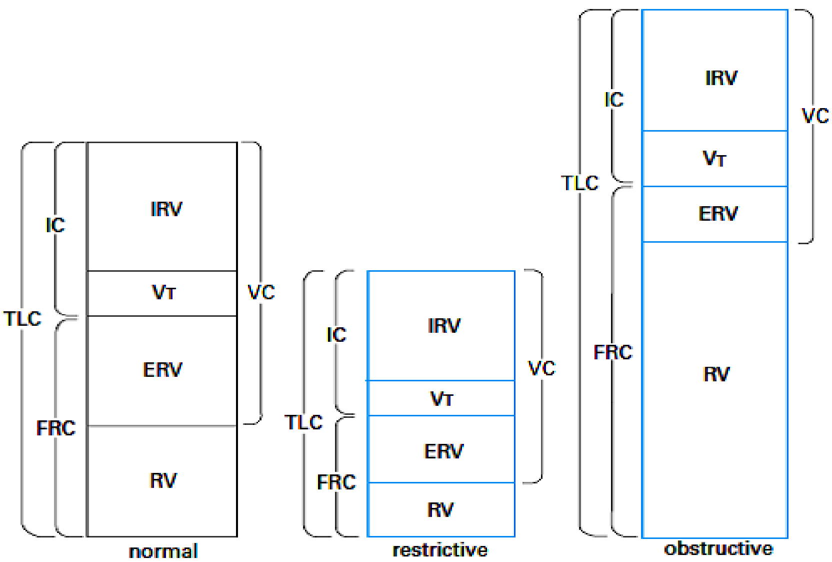


Figure -11 .Alterations in lung volumes & capacities in obstructive & restrictive diseases[22]

Figure-11 shows that TLC & FRC is decreased in restrictive lung disease, while it is increased in obstructive lung disease.

<u>Interpretations of pulmonary function test:</u>

The first & foremost step in the performance & interpretation of spirometry is the issue of test of accuracy & quality.[32] PFT interpretations should be clear, concise and informative. The clinical decision is made based on the interpretation of the results of PFTs which depends on the following

1. Estimating the pre & post-test probability of disease
2. Quality of the test results,
3. Eliminating false-positive and false-negative interpretation,
4. Based on the test results themselves and comparison with reference values.[31]

The VC, FEV_1, FEV_1/VC ratio & TLC are the basic parameters used to properly interpret lung functions.[31]In 2012, the Global Lung Initiation (GLI) {task force of European Respiratory Society} provide a normative values for males and female over 3-95 yrs age group .The recommended practice for identifying a spirometric abnormality is to use lower limit of normal which is based on the individual's sex, age, height and ethnicity. The reference equation for lower limit of normal is derived from a population study, which is the mean predicted value (based on pt's sex, age height) minus 1.64 times the standard error of the population study. In normal spirometry FVC, FEV1& FEV1/FVC ratios are above the lower limit of normal.[24]

The ATS recommended the use of lower limit of normal (LLN) for FVC & FEV1 which is 80% of predicted value as a cut off for adults.[24] Both Goble Lung Initiation (GLI) and Third National Health and Nutrition Examination Survey (NHANES) provide separate lower limit of normal (LLN) for spirometric parameters. GOLD criteria use lower limit of normal (LLN) for diagnosing pulmonary defect < 70% of predicted value as a cut off for adults for diagnosing pulmonary defect.[30] According to Third National Health and Nutrition Examination Survey (NHANES), lower limit of normal (LLN) is below 5 th percentile of spirometric data.[30]

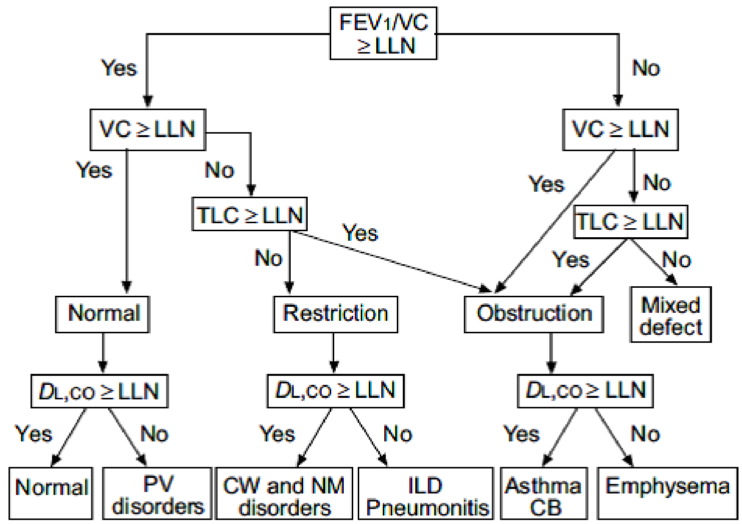


Figure-12. Simplified algorithm to assess the pulmonary functions[32]

Figure -12 is the simplified algorithm used to assess lung function in clinical practice. It presents classic patterns for various pulmonary disorders.

Step-1: The first step in interpretation of pulmonary function test is to determine forced expiratory volume in one second

(FEV1)/ VC ratio ≥ LLN or not .Then consider FVC, if FVC ≥ LLN then it is normal.

If not then check TLC.

Step-2: Total lung capacities (TLC) are or exclude the presence of a restrictive defect when VC is below the LLN.

Step-3: The measurement of diffusing capacity for carbon monoxide (DLCO) with the predicted value adjusted for hemoglobin is also included in this algorithm. In the mixed Pulmonary defect group, the DLCO patterns is same for both restriction and Obstruction.[31]

Disadvantages of this chart:

This flow chart is not suitable for assessing the severity of upper airway obstruction, any abnormality in pulmonary vasculature (PV),chest wall(CW)& neuromuscular(NM) disorders , interstitial lung diseases(IL), chronic bronchitis(CB).[31]

<u>Methods of assessing obesity:</u>

The stature (Height), body weight & built of an individual could influence the pulmonary function. Various methods are present for assessing obesity like waist circumference, waist to hip ratio, body mass index, skin fold thickness.

(1).Body Mass Index:

BMI assessment is a powerful tool for categorizing individual's weight in health & disease. BMI measures the adiposity & body composition among adults & children.[3] It is an index of weight for height for categorizing overweight and obesity in adults.[33] It is commonly used to assess body fatness and it is called as "Quetelet Index". It is accepted as practical tools to define and screen overweight or obesity by the international task force on obesity.[3] BMI is a global measure of body mass that includes both fat and lean mass and takes no account of differences in fat distribution.[34] The lung volume reduces as the BMI increases which is due to a direct mechanical effect on lung volumes. The distribution of body fat can also modify the relationship between BMI and lung volumes.[34]

Table -1. The International Classification of adult Underweight, Overweight and Obesity according to BMI.[35]

Classification	BMI(kg/m²)	
	Principal cut-off points	**Additional cut-off points**
Underweight	**<18.50**	**<18.50**
Severe thinness	<16.00	<16.00
Moderate thinness	16.00 - 16.99	16.00 - 16.99
Mild thinness	17.00 - 18.49	17.00 - 18.49
Normal range	**18.50 - 24.99**	**18.50 - 22.99**
		23.00 - 24.99
Overweight	**≥25.00**	**≥25.00**
Pre-obese	25.00 - 29.99	25.00 - 27.49
		27.50 - 29.99
Obese	**≥30.00**	**≥30.00**
Obese class I	30.00 - 34.99	30.00 - 32.49
		32.50 - 34.99
Obese class II	35.00 - 39.99	35.00 - 37.49
		37.50 - 39.99
Obese class III	≥40.00	≥40.00

(2).**Waist Circumference:**

Waist circumference is one of the predictor of obesity for abdominal & non abdominal fat. WC is a more convenient measure than WHR and is less likely to be influenced by sex or degree of obesity. WC is a better correlate & is an indicator of visceral obesity than BMI[2]. Respiratory function is determined by interaction of lungs , chest wall & muscles function. Fat in the abdomen & thorax has direct effect on the downward movement of the diaphragm & chest wall properties where as fat in the hip & thigh doesn't have any direct mechanical effect on the lungs.[29,36]

Thus truncal obesity causes restriction of outward movement of abdominal muscle wall. The mechanical effects of the intra abdominal pressure on the diaphragm are the main reason for the association of central obesity and compromised lung. WC showed a consistently association with pulmonary function across the BMI categories.[36]

(3) .Waist To Hip Ratio:

Waist-hip ratio is the ratio of Waist Circumference and Hip Circumference and is the measure of central pattern of fat distribution[37]**.**Increase in waist–Hip circumference are indicators of abdominal fat deposition[16,36], which can lead to deterioration of lung functions in both mildly & morbidly obese individuals . This is because of the limited diaphragm descent & lung expansion[16]. Waist to hip ratio (WHR) is highly correlated with abdominal fat mass and is often used as a surrogate marker for abdominal or upper body obesity. The predicted normal WHR in men is 0.93 and in women it is 0.83.[38]

According to Anuradha R.Joshi et al , the amount of body fat and central pattern of fat distribution are related to lung function via several mechanism such as mechanical effects on the diaphragm and chest wall causes changes in compliance and in the work of breathing and the elastic recoil.[38]

(4). Skin Fold Thickness:

Body fat percentage measurements is an excellent to good internal consistency and greater reliability for male subjects when compared with female counterparts.[33] The body fat percentage was estimated by using the method of Durnin and Womersley et al. Skin fold measurement is widely used body composition testing method for assessing body fat percentage. A skin fold caliper is used to measure the skin fold thickness at 4 different sites on the left side of the body. Extremity skin folds are measured at the triceps and biceps and trunk skin folds were measured at the supra iliac and sub scapular areas. The skin fold was picked up between the thumb and the forefinger and 3 consecutive readings are taken at each site 5 seconds after applying caliper. The average of the three readings at each site is calculated.[38] Abdominal & thorax have direct mechanical effect on lung where fat in the hip & thigh doesn't have any direct mechanical effect. Abdominal fat measurement using waist circumference, waist-to-hip ratio, abdominal height and thoraxic or upper body fat measurement using sub scapular skin fold thickness, biceps skin fold thickness are associated with reduced lung volumes in obese individual. [29,34]

Systemic complication related to obesity:

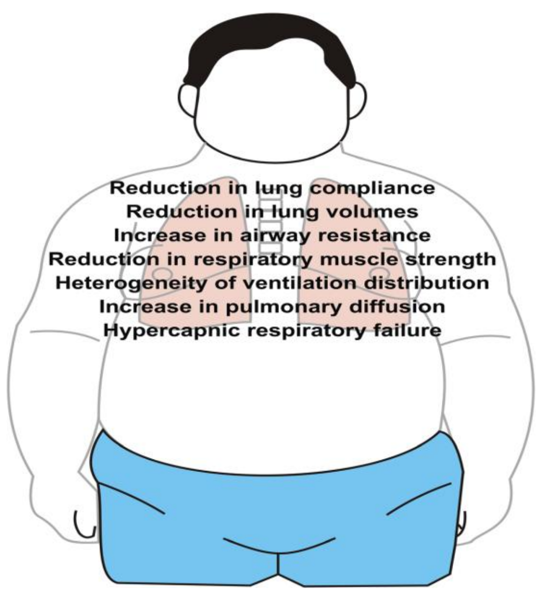
Metabolic and structural changes caused by overweight makes the obese individual more susceptible to various diseases like cardiovascular diseases, metabolic disorders, pulmonary renal and biliary diseases, obstructive sleep apnea and some types of neoplasm.[17]

The patho physiology of lung disease due to obesity is as follows

Adipose tissue is an energy storage endocrine organ which is composed of adipocytes, fibroblasts, endothelial cells and immune cells. These cells secrete hormones and cytokines (adipokines) that exert endocrine, paracrine, and autocrine functions. These adipokines induce the production of reactive oxygen species (ROS), which trigger oxidative stress which in turn leads to increased production of other adipokines. During this process oxygen free radicals are produced by the immune cells which promotes a systemic pro inflammatory state.[39] These pro inflammatory cytokines is associated with hypoplasia of the lungs, atopy, bronchial responsiveness and increased risk of asthma in obese individual.[17] It also contributes to systemic inflammation in COPD & asthma.[40]

Obesity and lung function :

Obesity affects various resting respiratory physiologic parameters such as spirometric measures, lung volumes, lung compliance, work of breathing, neuromuscular strength, respiratory resistance, diffusing capacity & gas exchange.[40]



Physiologic Parameter	Effect of Obesity
Respiratory Compliance	Decreased
Respiratory Muscle Strength	Decreased
Work of Breathing at Rest	Increased
Vital Capacity (VC)	Normal or Decreased*
Forced Expiratory Volume in One Second (FEV_1)	Normal or Decreased
Ratio (FEV_1/VC)	Normal, Increased or Decreased
Maximal Expiratory Flow Rates at Low Lung Volumes	Decreased
Longitudinal loss in FEV_1 and VC	Increased
Expiratory Reserve Volume (ERV)	Decreased
Functional Residual Capacity (FRC)	Usually Decreased
Residual Volume (RV)	Normal
Inspiratory Capacity (IC)	Normal or Increased
Total Lung Capacity (TLC)	Normal or Slightly Decreased
Airway Resistance	Increased
Specific Airway Conductance	Normal
Diffusing Capacity	Variable
Alveolar arterial oxygen tension gradient $[P(A\text{-}a)_{O_2}]$	Increased

Table-2 Effects of obesity on physiologic parameters

(1). <u>Obesity & Impaired Respiratory Mechanism:</u>

In obese individuals, the mechanism of the contraction of diaphragm pushing the abdominal contents down and forward & contraction of the external intercostals muscles pulling the ribs upward and forward is impaired. This is due to deposition of excess body fat surrounding the chest and the abdomen which limits the action of the respiratory muscles. These structural changes in the thoraxic-abdominal area restrict diaphragmatic mobility and rib movement, which causes changes in the dynamics of the respiratory system and reduces its compliance, leading to mechanical impairment of the respiratory muscles.[39]

(2).<u>Obesity & alteration in dynamic respiratory mechanics</u>

Reduction in resting expiratory reserve volume (ERV) & end expiratory lung volume (EELV) forces the obese subjects to breathe close to residual volume. This will limit the expiratory flow & does not allow EELV to decrease. During activity air trapping is increased in obese individual due to increase in ventilation. This causes false normalization of EELV allowing near normal tidal volume.[40]

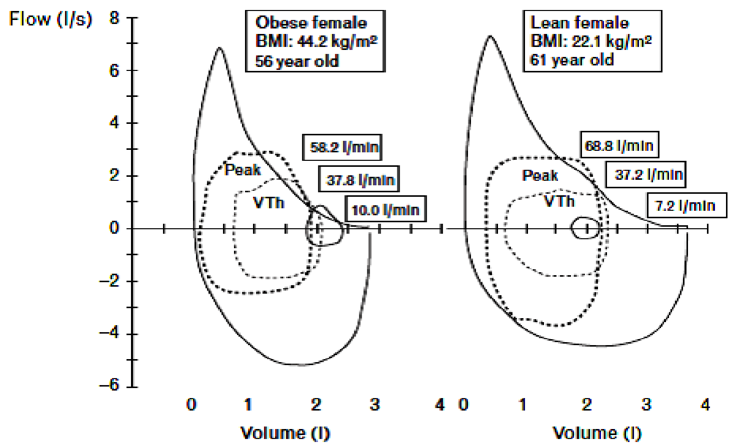


Figure -13.Comparison of Flow–Volume Loops in obese and normal-weight women

Figure -13 shows Tidal flow–volume loops at rest, ventilatory threshold, and peak exercise plotted within the respective maximal flow–volume loops in typical obese and normal-weight women .In normal weight female there is an increase in tidal volume by encroaching on the inspiratory reserve volume with little change in end-expiratory lung volume. But in obese female there is a significant limitation of tidal expiratory flow at rest and a large increase in dynamic end-expiratory lung volume (EELV) occur during peak exercise.[40]

(3).<u>Obesity & Reduction in lung compliance:</u>

Obesity is characterized by a stiffening of the total respiratory system due to combination of effect on lung & chest wall compliance. In obese individual, the most important PFT change is decrease in the lung compliance. It is due to increased weight of chest wall & higher position of diaphragm in the thoracic cavity resulting in decreased lung function which subsequently leads to increase in work of breathing.[26]

Other factors which cause reduction in the lung compliance are

- increased pulmonary blood volume ,
- closure of dependent airway,
- formation of small areas of atelectasis ,
- Increased alveolar surface tension due to reduction in FRC.[29,34]

(4). <u>Obesity & reduction in lung volumes:</u>

Fat deposition in obsess individual alter the pulmonary functions such as reduction in Functional Residual Capacity (FRC), Expiratory Reserve Volume (ERV) and Total Lung Capacities (TLC).[39]

1. The FRC is reduced in obesity which reflects a shift in the balance of inflationary & deflationary pressures on the lung due to mass load of adipose tissue around the rib cage & abdomen in the visceral cavity.[34, 39] This elevates the intra-abdominal pressure which is transmitted to the chest. This reduces FRC and ERV and requires patients to breathe in a less efficient part of their pressure-volume curve, which in turn increases the work of breathing.[39]
2. ERV is reduced in obesity due to deposition of fat in the thoraxic-abdominal region. It is the most common & consistent indicator of obesity.[39] Reduction in ERV leads to abnormalities in ventilation distribution, with airway closure in the dependent zones of the lung and inequalities in the ventilation-perfusion ratio.[39]
3. The TLC is reduced due to mechanical effect of the adipose tissue; this is because of reduction in the downward movement of the diaphragm and increased abdominal mass, thereby limiting the lung expansion during inflation.[34]

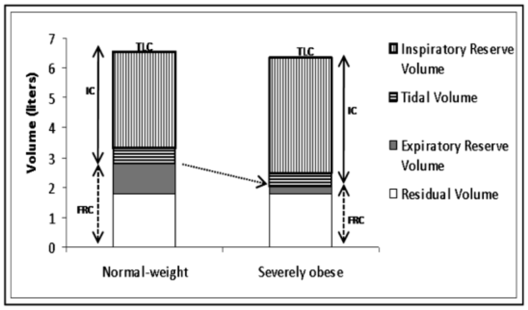


Figure -14. The effect of obesity on lung volumes

Figure 14 shows the effect of obesity on lung volumes. Expiratory reserve volume (ERV) & FRC (ERV+ RV) is decreased in obesity. RV is usually relatively well preserved. Tidal volume is reduced, but Total lung capacity can be normal or slightly reduced. [41]

- Obesity cause decrease in the tidal volume due to increased stiffening of the respiratory muscle system which results in the rapid & shallow pattern of breathing.[37] The modulation of airway smooth muscle contractility by regular tidal stretching and deep inspirations is unimpaired in mild to moderate obesity.[31]
- A thorax with a large amount of subcutaneous fat over the chest may lead to a change in the balance between the elastic recoil of chest wall & lung –chest wall Compliance.[25]

Obesity generally does not cause reduction in FEV1 or FVC unless patients are massively obese. FEV1/FVC ratio is usually preserved.[54] The pattern of obesity is more significant than BMI alone. Abdominal obesity is generally correlated with reductions in FEV1 and FVC except in certain women and in certain age groups.[42]

(5). <u>Obesity & cost of breathing:</u>

The oxygen required for breathing accounts for the total energy required by the respiratory muscles to overcome respiratory mechanical factors such as airway resistance, lung compliance, chest wall resistance, breathing inertia, antagonistic activity of respiratory muscles, chest wall distortion, gas compressibility, and work on the abdominal viscera . Many of these components are affected by increase in adipose tissue in & around the rib cage especially during exercise. In lean subjects, the oxygen cost of breathing is 1.2 ml of O_2/L of ventilation, but it is three times increased (3.45 ml/L) in moderately obese subjects.[43]

The cost of breathing is greater in obese individual due to deposition of adipose tissues around the chest wall[41]. The energy cost of breathing (WOB) is the ratio of inspiratory power of breathing at rest to the critical inspiratory power (W_{rest} / W_{crit}) which reflects the oxygen consumed by the respiratory muscle.[44]

(6). <u>Obesity & Work Of Breathing</u>:

The obese individual require more respiratory effort to overcome respiratory system elasticity to maintain appropriate levels of ventilation .Because of low FRC & less complaint portion of the pressure –volume curve ,obese individual require increased ventilation & high flow to perform the MVV maneuver.

Certain studies showed that there is air trapping in obese individual which has been confirmed by plethysmograph which shows an increase in RV to TLC ratio. Tidal breathing is affected by expiratory flow limitations (EFL) & intrinsic positive end expiratory pressure (PEEPi) which is increased in supine position due to increased diaphragmatic load in the supine position.[10,45] Morbid obese individual may develop tidal expiratory flow limitations (EFL) which is seen during quite breathing. This tidal EFL promotes dynamic pulmonary hyperinflation which results in the development of intrinsic positive end expiratory pressure (PEEPi). PEEPi is the end expiratory elastic recoil pressure of the respiratory system which is due to incomplete expiration .This may produces a threshold load on inspiratory muscles before inspiratory flow of next breathing cycle begins. PEEPi also imposes an additional mechanical load on the inspiratory muscles, thereby it increases the WOB.[10]

(7). <u>Obesity & breathing pattern:</u>

In 1991 Yang and Tobin introduced that the ratio of breathing frequency to tidal volume (fR /VT) is an index in predicting weaning outcome, which is a measure of rapid shallow breathing.[46] According to Luce et al, it is assumed that for a given minute ventilation (VE), breathing with high frequency and lower tidal volume may decrease oxygen cost of breathing.[47] This combination of smaller VT & higher breathing frequency occurs when the rate of ventilation increases .There will be an increase in ventilation and dead space (*V*D/VT) ratio where rapid breathing is detrimental. (Macklem et al , Misuri et al).[44]

In order to avoid diaphragmatic muscle fatigue, work of breathing is optimized by adopting a more rapid & shallow breathing pattern. The total breath time tended to be shorter compared to healthy subjects because of the consequence of the higher breathing frequency. Both inspiratory and expiratory times were shorter in the obese group compared with normal group. Increase in respiratory frequency was due to a significant decrease in the expiratory time per breath .Any alteration in the ratio of inspiratory to expiratory time (*T*I/*T*E) indicates an alteration in central breath timing duty cycle (TI/TTOT).[44]

The high breathing frequency to tidal volume (fR/VT) ratio is observed in obese subjects, which is the manifestation of respiratory muscle weakness. An increase in frequency to tidal volume ratio is associated with an increase in the ratio of mean inspiratory pressure to maximal inspiratory pressure (PI/PImax) & the ratio of inspiratory time to the total time (TI/TTOT) of the respiratory cycle.[44]

(8). Obesity & Respiratory muscle strength:

Due to the load imposed on the diaphragm, respiratory muscles function is impaired with increasing obesity. Respiratory muscles dysfunction is due to increased resistance imposed by the excess fatty tissue on the chest and abdomen, which causes mechanical disadvantage to these muscles.[48]

Respiratory muscle strength can be assessed by measuring maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP). In obese individuals, both MIP and MEP are reduced. This reduction in MIP and MEP is due to distension of the diaphragmatic muscles, increased respiratory effort, and ineffective muscle biomechanics caused by fat deposition in the thoracic and abdominal regions.[49] In the supine position, the weight of the abdomen in obese individuals causes the diaphragm to ascend into the chest, resulting in the closure of small airways at the base of the lung and thereby generating an intrinsic positive end-expiratory pressure that results in increased ventilatory work and consequent muscle impairment.[42,48]

Evidence showed that bariatric surgery cause a significant reduction in BMI from 41.5 kg/m2 to 31.7 kg/m^2which showed improvement in inspiratory (PI max) & expiratory (PE max) respiratory muscle strength by 21% & 22% & improvement in respiratory muscle by 13%, which is greater than FVC (9%) , FEV_1(3%) , LV(7-10%) showing that weight reduction has direct effect on respiratory muscle function.[50]

(9). <u>Obesity & airway closure</u> :

Mechanical properties of the airway are resistance and reactance, which are highly dependent on lung volume. Any reduction in FRC will affect airway. Increase in Respiratory resistance in obese indicates reduction in airway caliber throughout the tidal breathing cycle. In obese individual, the reduction in airway caliber will cause reduction in lung volumes rather than to airway obstruction.[34]

The obese individual is at increased risk of airway closure and abnormal ventilation distribution. It is due to reduction in FRC to the extent, it approaches RV. Indicators of gas trapping and airway closure, such as RV[51]and closing capacity[52], are usually not increased in the obese individual at rest. Certain studies demonstrate that when closing capacity exceeds FRC because of low FRC cause the airway closure to occur within the tidal breaths.[34]

(10). <u>Obesity & oxygenation, ventilation, perfusion & gas exchange:</u>

Studies done using imaging techniques reveal the abnormalities of regional ventilation in some obese individuals. In upright posture non obese individual shows the distribution of regional ventilation greatest in the lower dependent lung zones but it is decreased in the upper zones. This is reversed in obese individuals.[34]

Holley et al. found that in obese individual ventilation was preferentially distributed to the upper zones of the lungs, leaving the lower dependent zones relatively under ventilated with marked reductions in ERV to 21% of the predicted value.[34,53] But according to Demedts et al the reduction in regional ventilation in the lower zones in obese subjects is due to air trapping at the lung bases. He suggests that limitations in chest wall and diaphragm movements alter the configuration of the lungs and enhance basal air trapping at low lung volumes.[54] The distribution of perfusion is predominantly to the lower zones, so those obese individuals with a reversal of the normal distribution of ventilation are at risk of regional ventilation-perfusion mismatch in the dependent zones of the lung.[55]

Obese patients have a normal[54] or slightly reduced PaO2.[56] Obesity causes a mild widening of the A-aO2 gradient which is caused by ventilation–perfusion mismatch.[43] In sitting[51]& in the recumbent position[57]the base of the lungs of the obese individual are relatively over perfused and under ventilated which is due to the closure of small airways in dependent lung zones.[57] This results in reduction in ERV with a relatively unchanged RV.[41]

(11).<u>Obesity & exercise:</u>

The increased metabolic requirement in obesity needs additional energy to move heavier body parts during exercise .This reduces the mechanical efficiency of peripheral muscle & increase in WOB & VO2.[58] Any abnormality of A-aO_2 gradient, and PaO_2 are improved during exercise.[59] Augmented tidal volumes help to open the closed, dependent lung units, which are the primary cause of the increased A-aO2 gradient.[42] In addition to having a lower A-aO2 gradient, obese patients augment their oxygen intake by increasing their tidal volumes and respiratory rates during exercise, similar to normal weight subject. They augment their minute ventilation more than normal-weight subjects by burning more oxygen. This is mainly through a higher respiratory rate because their tidal volumes are not generally greater.[41,60] It is due to central breath timing, but some studies relates it to body fat distribution leading to impaired diaphragmatic excursion, which causes an inability to augment exercise tidal volumes any further.[41]

(12). Obesity & Impaired Upper Airway Mechanics :

As obesity progresses, sleep apnea develops nocturnal disturbances in sleep & gas exchange which can trigger further elevation in oxidative stress, inflammatory cytokines & humoral factors ,which aggravating pharyngeal neuromuscular dysfunction.[61]

Upper airway obstruction during sleep can result from alterations in either passive mechanical pharyngeal properties or disturbances neuromuscular control. Fatty deposits around the neck and pharyngeal lumen may increase upper airway collapsibility.[60,62] In addition, central adiposity impose mechanical loads on the upper airway which reduces lung volume[62] and predisposes to upper airway collapse and increases sleep apnea severity.[63] This is a major risk factors for increased upper airway resistance & collapsibility.[10]

According to Kirkness et al (2008) Passive Pcrit had a predictive power of 0.73 (95% CI: 0.65– 0.82) in predicting sleep apnea status.[64]

(13). Neuro hormonal Influences:

Stimulation of the reticular activating system facilitates breathing. Sustained nocturnal hypoxemia increases the arousal threshold ,which impair the normal defense mechanism that operate to minimize the insult of abnormal breathing & gas exchange during sleep.[10] Obesity is associated with an important hormone leptin which is a marker of systemic & vascular inflammation.[25] The presence of circulating leptins in obesity are found to increase the ventilation to compensate for work & vco_2 resulting in low respiratory drive[65] which may lead to hypercapnic respiratory failure.[66]

Insulin like growth factor I has a pleotropic role in metabolism, ventilator control, muscle function & cardiovascular protection. Deficient insulin like growth factor, might play a role in development of hypercapnea in obese individual through altered ventilatory drive & respiratory muscle weakness.[67]

(14).<u>**Complications of obesity :**</u>

Multiple mechanisms through which obesity increases morbidity and complicates management are

1). Obstructive Sleep Apnea (OSA)

2). Obesity Hypoventilation Syndrome (OHS)

3). Acute Respiratory Distress Syndrome (ARDS). [68]

[1].Obesity & obstructive sleep apnoea (OSA) :

OSA is a common condition characterized by recurrent episodes of upper airway obstruction during sleep, which are associated with arterial oxygen desaturation and repetitive arousals resulting in disrupted sleep and excessive daytime sleepiness.[68]

1. Obesity is the known risk factor for the development of OSA.[69]
2. The prevalence of OSA increases with age which is associated with high rates of morbidity and mortality;
3. The peak incidence occurs at 55 yrs of age
4. It is more prevalent in males than in females in the ratio of 2:1.[70]
5. Central obesity and increased neck circumference are predisposing factors for OSA.[69]

[2]. Obesity Hypoventilation Syndrome (OHS)

"Obesity hypoventilation syndrome (OHS)" is defined by the triad of obesity (BMI ≥ 30 kg/m2)[71], daytime hypoventilation {hypercapnia: $PaCO_2$ ≥45 mm Hg (6 kPa) and sleep disordered breathing.[72] The prevalence of OHS is increasing with increasing BMI. There are several contributing mechanisms including:

(1). Excessive loading of respiratory muscles by the mass of centrally deposited fat;

(2). Disordered gas exchange, particularly when recumbent, because of atelectasis in dependent Lung zones;

(3). Obesity related upper airway narrowing; and

(4). Disordered ventilatory control.[68]

[3]. Obesity & Acute Respiratory Distress Syndrome (ARDS)

When total respiratory compliance is considered in obese patients, the effects of obesity on the chest wall must be separated from the effects attributable to decreased lung compliance, as seen in acute lung injury (ALI) and acute respiratory distress syndrome (ARDS). This distinction has major implications for the application of mechanical ventilation in obese patients.[68]

Underweight & Lung Function :

Under nutrition reduces diaphragm muscle fiber & cause deleterious changes in diaphragm muscle structure that ultimately leads to reduction in diaphragm ability to generate force.[73] Underweight will have a significantly reduced lung function. Lower level of muscle mass in underweight causes low dynamic lung function.[37] Low body fat percentage may be associated with lower sympathetic activity such that it increases the bronchial tone resulting in decreased air flow.[37] Under nutrition reduces diaphragm contractility by reducing respiratory &

other muscle mass.[74] It is associated with severe airflow obstruction due to low FEV1, FVC & PEFR which is directly correlated with high pulmonary & cardiovascular morbidity & mortality.[6] There will be depletion of body resources of proteins & calories, associated with wasting of skeletal muscle including respiratory muscle, which results in reduced FVC & FEV.[16]

OTHER RELATED ARTICLES

In 2014, a retrospective study was done by JOYASHREE BANERJEE et al to correlate the Body Mass Index (BMI) with lung function parameters in 424 non-asthmatics subjects in R.G Kar Medical College. They found that there was a significant association between lung parameters in obese group, more pronounced in females than males.[75]

A cohort study was done by MARGA B BEKKERS et al in the population of 8-12 yrs old children, where they analyzed the association of BMI & WC with lung functions, in which they found that a persistent high BMI or large WC is not associated with lower FVC& FEV1, but the FEV1/FVC was significantly lower in children with high BMI or large WC than with normal BMI or WC. Girls & boys with a persistent high BMI or large WC status had statistically low FEV1/FVC ratios.[76]

A comparative study of vital capacity between normal weight & underweight women in their 20s was done in 34 South Koreans by JIN –TAE HAN et al in 2012, they suggest that the underweight women had significantly lower FVC & FEV1 than the normal weight group .MVV of the underweight group was also lower than that of normal weight group, but the difference was not significant. They concluded that low body weight is related to reduction of vital capacity in women.[77]

A cross sectional study was conducted by AHAMAD AZAD et al in 2014 to evaluate lung function & develop a prediction equation in underweight & normal weight young adults residing in SOCATANISH city near ZANJAN. They concluded that dynamic lung functions like FEV1 & FVC were significantly lower than the reference value in both groups.[16]

A cross sectional study was conducted on 85 Gujarat Indian adolescent boys of 17-21 yrs. They found that the dynamic lung functions like FEV1, FEV6 , PEFR were significantly lower in underweight boys when compared to normal weight boys. From that they concluded that BMI had a significant positive correlation with dynamic lung function .Among underweight boys, BMI & fat mass index was directly associated with dynamic lung functions.[6]

In 2012, SONU AJMANI evaluated the effect of abdominal fat on dynamic lung function tests in 120 healthy sedentary employees in the age group of 30-40 yrs, who worked in the air – conditioned environment of a private motor vehicle show room. From their study, they concluded that PFT variables of low BMI & overweight BMI group were compared with that of normal BMI group. The result showed that there is inverse relation between BMI, WC & FEV1/FVC indicating an obstructive airway disease worsening in genetically prone high BMI subjects.FEF 25-75 varies proportionately with BMI indicating malnutrition and thus unfavorably influences the lung functions.[36]

SUGANYA et al in 2016 performed a study on influence of BMI on PEFR. This study was done in 120 subjects in the age group of 18-25 yrs. In this study they assessed the lung functions by simple methods like PEFR & BHT; they suggest that there was significant reduction in the lung function in underweight & obese when compared with normal weight. Female had drastically reduced lung function (PEFR, BHT) when compared with males.[78]

A correlation study of BMI & PFT among 150 south Indian adult males was done by G. K. SUDHIR et al in 2014, as obesity is the newer chronic non-communicable disease, FVC was significantly increased in the obese group than in normal.FEV1 showed a reduction in obese when compared with normal .As BMI increases there is restrictive type followed by mixed & obstructive pattern of lung impairment. As increase in FVC with increase in BMI suggest an emphysematous change secondary to obstructive with greater degrees of obesity.[9]

A correlation study was done by ANUGYA et al to see the effect of BMI on gender difference in lung functions in Indian population in 2017.Their study showed that there was a negative correlation between BMI & lung function with increase in BMI, the FVC was decreased indicating the increase in the restrictive pattern of lung function.[79] This is in contrast to the result observed in the study mentioned above.

A cross sectional comparative study of obesity & pulmonary functions among Indian men was done by SHINDE RAVINDRA JANARDAN etal .They found that there was a significant difference in FVC &FEV1 in non obese & obese study subjects. But there was no significant difference found in FEV1/FVC ratio, PEF & MEF. They suggest that obesity has significant effects on lung function of Indian men & the greatest effects were on FVC & FEV1.[80]

The effects of BMI on dynamic lung volumes in young males was studied by SRILEA GHOSH CHOWDHURY et al in 2016.Their study results showed that there was a significant lower value of FVC as well as FEV1, as compared to normal subjects. The alteration in FVC, FEV1, ERV suggest that lung function impairment is due to damage to the chest mechanics caused by obesity. All of these factors contributed to a reduction of the MVV.[81]

Influence of BMI on PFT was studied in Punjabi youngster population by KOHLI PG etal in 2017. The result of their study showed that FVC, PEFR & MVV were found to be lower in case of the females belonging to all BMI sub groups (underweight, normal weight , overweight & obese), when compared with the corresponding males. This is due to greater respiratory muscle strength as well as greater compliance in males as compared to females.[82]

MATERIALS & METHODOLOGY

Study Design: Prospective Cross Sectional Study

Study Setting:

This study was conducted during the period of December 2016 to June 2018 at Trichy SRM Medical Hospital & Research center, Irungalur, Trichy. Anthropometric measurements & Spirometry recording were performed at the Research lab of Department of Physiology.

Study Duration: one & half years

Selection of Subjects:

The healthy volunteers were selected for this study using simple randomization technique.

Sample Size:

The calculated sample size was 111 with 90% power and 95% confidence interval[11].

Study Population: Male medical Students studying in TSRMMCH& RC, Irungalur , Trichy.

Inclusion criteria:

- Healthy male students,
- 3 categories of BMI {normal, underweight, overweight} were included in the study.

Exclusion criteria:

- Obese males,
- Students who are smokers & drug abusers ,
- with musculoskeletal chest deformity ,
- With respiratory & cardiovascular illness were excluded from the study[4] .

After obtaining ethical clearance from the institutional ethical committee of TSRMMCH&RC, the subjects was enrolled for the study. The subjects were explained about the study and procedure in detail. An informed written consent was obtained. The subjects were instructed to come to the clinical laboratory of department of physiology, TSRMMCH&RC between 4pm to 6 pm. A brief history and a thorough clinical examination was done to rule out any respiratory disorders.

Estimation of Body Mass Index and Waist & Hip Examination:

The participants were instructed to wear light clothing's during their visit. Height was measured in erect posture using a stadiometer to the nearest cm .Weight was measured in a standard weighing machine to the nearest kg with no shoes.[1] Body mass index (BMI) was calculated by "Quetelet's Index", as the ratio of weight in kg and height in meter square.

$$BMI = wt(kg)/ht(m).^{2}$$

Subjects were divided into 3 groups according to WHO classification of BMI.

- **Underweight: <18.5**
- **Normal: 18.5 to 24.9**
- **Overweight : >25.0**
- **pre obese : 25.0 to 29.9**
- **obese ->30.0**
    - **category I : 30.0 to 34.9,**
    - Category ii : 35.0 to 39.9,
    - Category iii : >40.0.[33]

Waist Circumference:

Waist circumference was measured as the minimum circumference between the costal margin and iliac crest in horizontal plane with the subject standing.[4]

Hip Circumference:

Hip circumference was measured as the maximum circumference in the horizontal plane over the buttock region[4].The waist - hip ratio provides an index of proportion of intra- abdominal fat.

Assessment of pulmonary functions:

Lung volumes were measured in a Computerized Spirometer in a quiet room in sitting position, after the procedure was demonstrated to the subjects. Pulmonary function test was assessed by using Computerized Spirometer "COSMED" which gives predicted value at ERS 93.For each subjects, three satisfactory efforts were recorded according to the norms given by American Thoraxic Society .

COSMED
The Metabolic Company

PROCEDURES:

- Spirometer calibrations were checked
- The test explained
- Hands Washed
- Instructions & demonstrations given to the subjects which include
    1. Correct posture with head slightly elevated
    2. Positioning of the mouth piece
    3. Rapid & complete inhalation
    4. Exhalation with maximal force
- Performance of maneuver
    1. After assuming the subject in correct posture
    2. Nose clip attached, mouthpiece placed in mouth & then lips closed around the mouth piece
    3. Rapid & complete inhalation performed with a pause of <1s at TLC
    4. Maximal exhalation done until no more air can be expelled while maintaining an upright posture. It should be quick forced expiration after maximum inhalation
    5. Repeat maneuvers for a minimum of three times, but not repeating the maneuvers for more than eight times and maximum value was taken.[20]

The following parameters were recorded

1. **FVC-forced vital capacity.**

2. **FEV1-forced expiratory volume at 1second.**

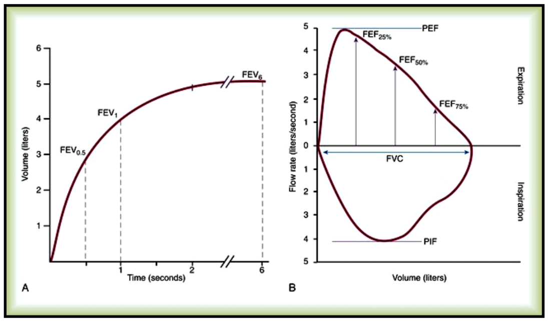


Figure-15.Volume –Time Curve & Flow Volume Loop

The subject produced at least three acceptable attempts (no artifacts, satisfactory start, at least 6 s duration and/or 1 s final zero-flow plateau), two of which were reproducible (<200 ml difference between the curves at FEV1 and FVC) .[83]

3. **SVC-slow vital capacity.**

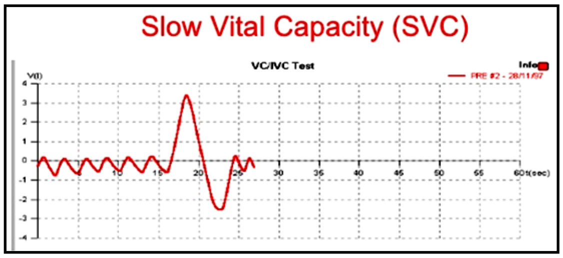


Figure-16.Slow Vital Capacity

For SVC, the attempt was deemed to be acceptable if the subject was observed to breathe into TLC then breathe out completely until flow had ceased for at least 1 s. SVC measurements were considered to be reproducible if the two highest attempts varied by less than 200 ml.[83]

4. **MVV-maximum voluntary ventilation.**

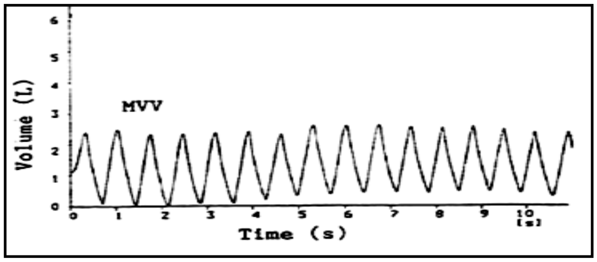


Figure-17. Maximum Voluntary Ventilation.

Maximal Voluntary Ventilation (MVV) is a relatively a shortest, used to evaluate a patient's ability to maintain an elevated minute ventilation. MVV is expressed in liters /min, the mouth piece was placed into the subject's mouth and was instructed to breathe quietly. When the subject settled, they were asked to breathe in and out as rapidly and deeply as possible for 10 seconds, and then MVV was calculated for one minute.[84]

5. **MIP-Maximum Inspiratory Pressure and MEP- Maximum Expiratory Pressure.**

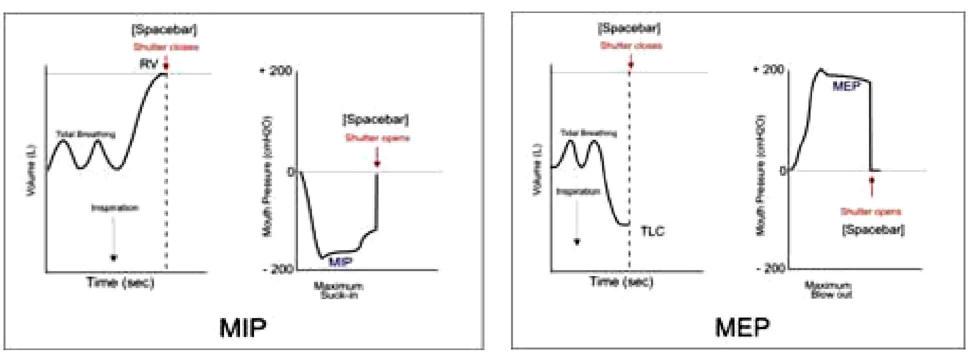


Figure-18.Maximum Inspiratory & Expiratory Pressures

MEP and MIP were used as indices of respiratory muscle strength. MEP and MIP measurements were made with the subject in the seated position. All subjects wore nose clips and pressed their lips tightly against the mouthpiece to prevent air leaks. MIP was measured starting at residual volume. MEP was measured starting at total lung capacity. The pressure measured was maintained for at least 1 s. Five repeated measurements were made, with a suitable rest pause between the measurements, until a plateau value was reached and no further learning effect was seen. MEP and MIP of 2 maneuvers that differed by 10% were recorded.[85]

Other parameters computed by the Cosmed spirometry:

- VC-vital capacity
- ERV-expiratory reserve volume.
- Vt –tidal volume

Statistical analysis

Data's are expressed as mean ± standard deviation. Statistical analysis is done using Statistical Package for Social Science (SPSS) software version 21. Relationship between BMI and spirometric parameters were analyzed using ANOVA test. Correlation between BMI and pulmonary function test were done using Pearson's Correlation test.

P value < 0.05 was considered to be statistically significant.

RESULTS

Table-3 . Descriptive Statistics

S.No	PARAMETERS	N	Min	Max.	Mean	S.D
1	**HEIGHT (cm)**	111	115.00	185.00	173.40	9.98
2	**WEIGHT (kg)**	111	48.00	120.00	68.74	16.21
3	**BMI**	111	14.63	39.54	22.70	5.27
4	**WC (cm)**	111	40.00	117.00	81.83	14.02
5	**HC(cm)**	111	43.00	126.00	95.58	13.04
6	**WHR**	111	0.19	1.16	0.83	0.10
7	**FEV1**	111	1.91	6.05	3.70	0.77
8	**FVC**	111	1.84	8.57	3.31	0.92
9	**FEV1/FVC**	111	38.00	112.00	87.58	13.13
10	**PEF**	111	3.02	10.90	7.56	2.00
11	**ERV**	111	0.05	7.84	1.40	0.90
12	**MVV**	111	18.00	177.00	117.29	27.34
13	**MIP**	111	9.00	96.00	36.98	19.719
14	**MEP**	111	11.00	66.00	33.78	15.29

Table -3 shows the descriptive statistics of all parameters that had been analyzed in the different categories of BMI .

The mean height & weight of the subjects included in the present study was found to be 173.41 ± 9.98 cm and 68.74 ± 16.21kg respectively .The average BMI was found to be 22.70 ± 5.27.The mean waist circumference & hip circumference was 81.84 ± 14.03 cm & 95.58 ± 13.04 cm with waist hip ratio of 0.83 ± 0.10.The pulmonary function parameters analyzed in the study were Forced Expiratory Volume at 1sec (FEV1) with mean value of 3.69 ± 0.78 litre/sec , Forced Vital Capacity (FVC) with mean of 3.31 ± 0.92 litre and FEV1/FVC ratio with mean value of 87.58 ±13.13. The mean Peak Expiratory Flow (PEF) was 7.55 ± 2.00 litre /sec, Expiratory reserve volume (ERV) was 3.01 ± 11.36 litre and Maximum Voluntary Ventilation (MVV) was 117.28 ± 27.34 litre per minute. The average maximum inspiratory (MIP) and expiratory pressures (MEP) were 36.98 ± 19.719 & 33.78 cm H_2o ± 15.28 cm H_2o.

Table-4. Comparison of height among Underweight , Normal & Overweight.

Group	Mean ± SD	95% CI	P-Value
Underweight	173.93 ± 5.52	171.54 to 175.29	0.825
Normal	173.73 ± 6.26		
Overweight	172.59 ± 15.29		

*p value<0.05, ** p value <0.01, *** p value <0.001

Chart -1. Comparison of height among Underweight , Normal & Overweight.

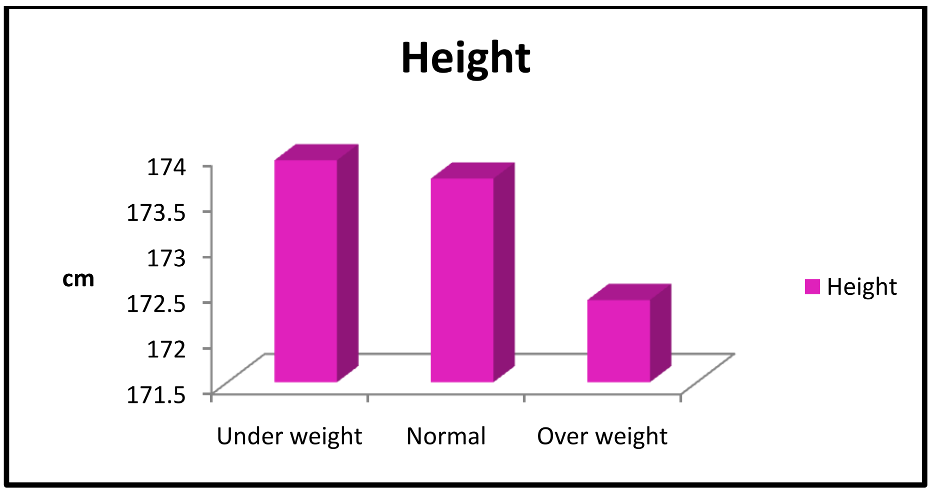


Table-4 & Chart -1 shows distribution of height in different categories of BMI. The mean height of the subject in Overweight group was 172.59 ± 15.29 cm ,which was lesser than the mean height of the subjects in underweight (173.93 ± 5.52cm) & in normal group subjects (173.73± 6.26 cm). This difference was not statistically significant (p value=0.825)

Table-5. Comparison of weight among Underweight , Normal & Overweight

Group	Mean±SD	95% CI	P-Value
Underweight	52.47 ± 2.92	65.69 to71.79	0.000***
Normal	65.78 ± 6.48		
Overweight	87.97 ± 9.58		

*p value<0.05, ** p value <0.01, *** p value <0.001

Chart -2. Comparison of weight among Underweight, Normal & Overweight.

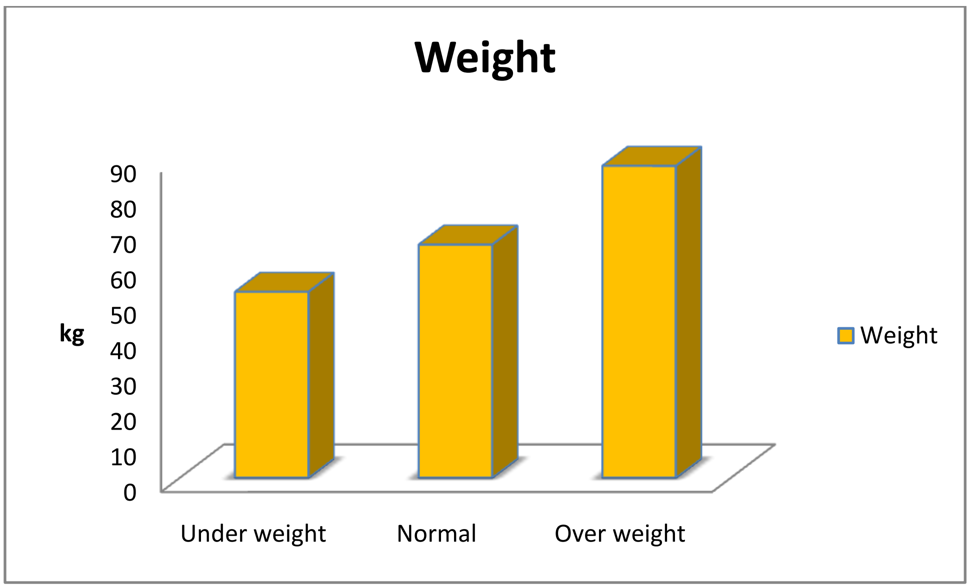


Table-5 & Chart -2 shows the distribution of weight in different categories of BMI. The measured mean weight in Overweight, normal & underweight group were found to be 87.97 ± 9.58 kg , 65.78 ± 6.48 kg and 52.47 ± 2.92 kg. The difference in weight among 3 groups of BMI was statistically significant (p <0.000)

Table-6. Comparison of waist & hip circumference among underweight ,normal & overweight

Group	Waist circumference			Hip circumference		
	Mean ± SD	**95% CI**	**P-Value**	**Mean ± SD**	**95% CI**	**P-Value**
Underweight	71.14 ± 6.95	79.20 to 84.48	0.000***	86.49 ± 8.27	93.13 to 98.03	0.000***
Normal	77.97 ± 8.53			93.70± 6.92		
Overweight	96.41 ± 11.36			106.57 ± 13.83		

*p value<0.05, ** p value <0.01, *** p value <0.001

Chart -3.Comparison of waist & hip circumference among 3 groups of BMI

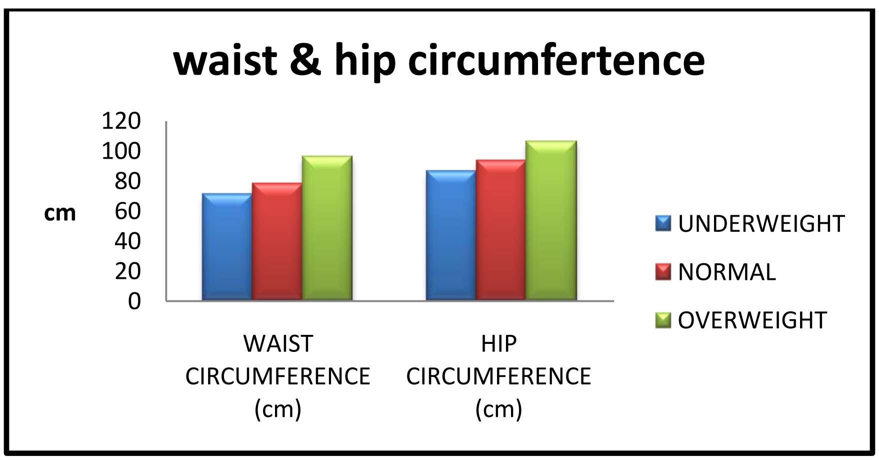


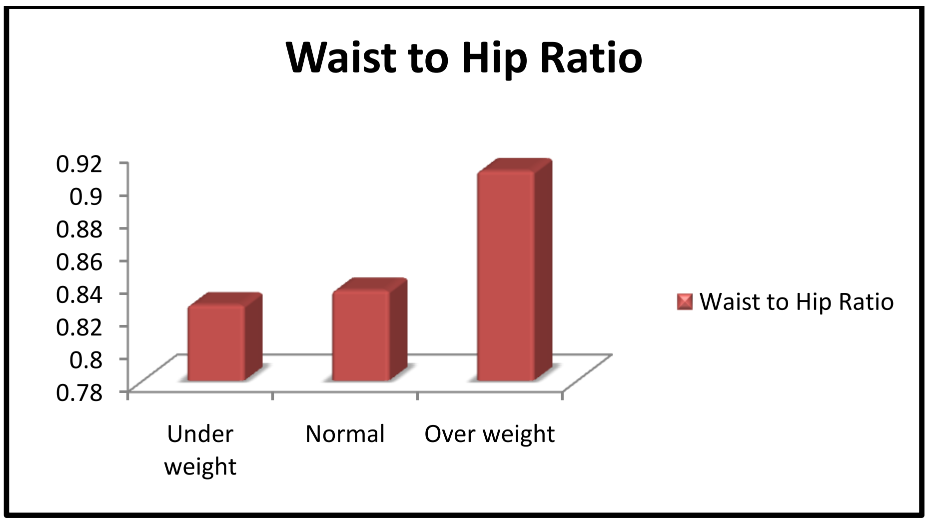
Table-6 & Chart -3 shows the distribution of waist & hip circumference in different categories of BMI. When compared with normal weight group, the observed hip circumference & waist circumference were found to be increased in overweight group(WC= 106.57 ± 13.83cm ; HC= 96.41 ± 11.36 cm) & decreased in underweight group (WC=71.14 ± 6.95 cm, HC= 86.49 ± 8.27 cm).It was highly significant (p < 0.001)

Table - 7. Comparison of Waist –Hip ratio among under weight, normal & overweight.

Group	Mean ± SD	95% CI	P-Value
Underweight	0.81 ± 0.01	0.86 to 0.19	0.000***
Normal	0.79 ± 0.02		
Overweight	0.89 ± 0.01		

*p value<0.05, ** p value <0.01, *** p value <0.001

Chart - 4. Comparison of waist –hip ratio among 3 groups of BMI



The mean value of Waist –Hip ratio observed in underweight, normal & overweight group was 0.81 ± 0.01, 0.79 ± 0.02 & 0.89 ± 0.01 .On comparison, the mean value of WHR in overweight group was found to be increased, there was not much difference in the mean value of WHR in normal & in underweight group which was highly significant (p <0.05) .

Table - 8. Comparison of Forced Expiratory Volume at first second among underweight , normal & overweight.

Group	Mean ± SD	95% CI	P-Value
Underweight	3.16 ± 1.07	3.381 to 3.72	0.003**
Normal	3.84 ± 0.71		
Overweight	3.66 ± 0.73		

*p value<0.05, ** p value <0.01, *** p value <0.001

Chart -5.Comparison of Forced Expiratory Volume at first second among 3 groups of BMI

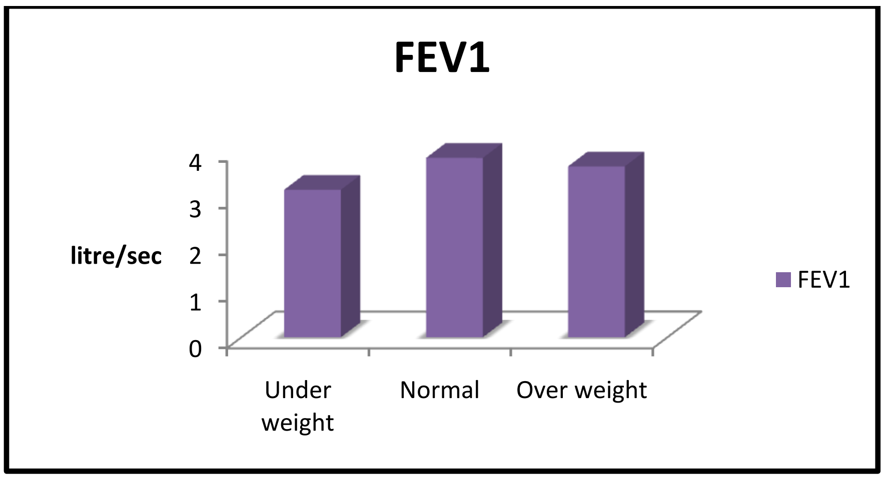


Table-8 & Chart -5 shows the distribution of pulmonary parameter forced expiratory volume at first second in different categories of BMI. The measured mean FEV1 in overweight group was 3.66 ± 0.73 litre/sec & in underweight group was 3.16 ± 1.07litre/sec & in normal group was of 3.84 ± 0.71 liter /sec .This test result shows that there is a significant variation in FEV1 among 3 groups (p < 0.01).

Table-9. Comparison of Forced Vital Capacity among Underweight , Normal & Overweight.

Group	Mean ± SD	95% CI	P-Value
Underweight	3.58 ± 0.89	3.290 to 3.612	0.15
Normal	3.54 ± 1.01		
Overweight	3.23 ± 0.60		

*p value<0.05, ** p value <0.01, *** p value <0.001

Chart -6. Comparison of Forced Vital Capacity among 3 groups of BMI

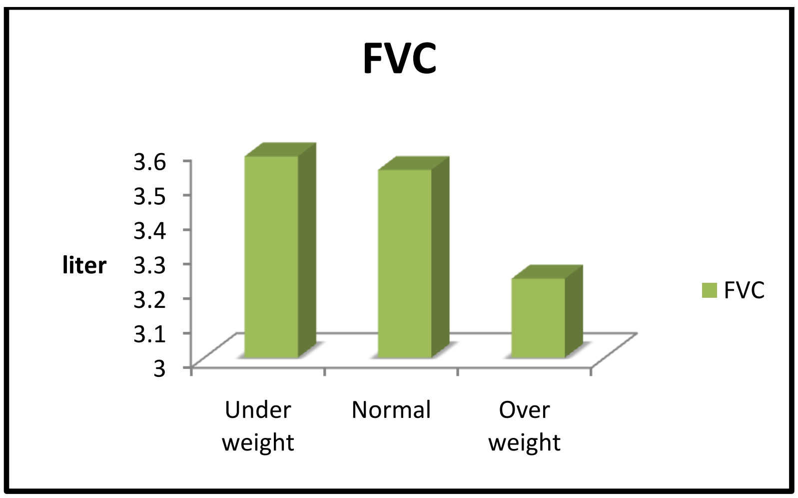


Table-9 & Chart -6 shows the distribution of pulmonary parameter Forced Vital Capacity in different categories of BMI . The mean value of FVC was increased in underweight group (3.58 ± 0.89 litre) but it was found to be decreased in overweight group (3.23 ± 0.60 litre) when compared with normal group (3.54 ± 1.01 litre) .It was not statistically significant .

Table -10 . Comparison of FEV1/FVC among Underweight , Normal & Overweight.

Group	Mean ± SD	95% CI	P-Value
Underweight	84±15.67	85.12 to 90.06	0.123
Normal	89.03 ± 12.03		
Overweight	89.73± 10.49		

*p value<0.05, ** p value <0.01, *** p value <0.001

Chart -7. Comparison of FEV1/FVC among 3 groups of BMI

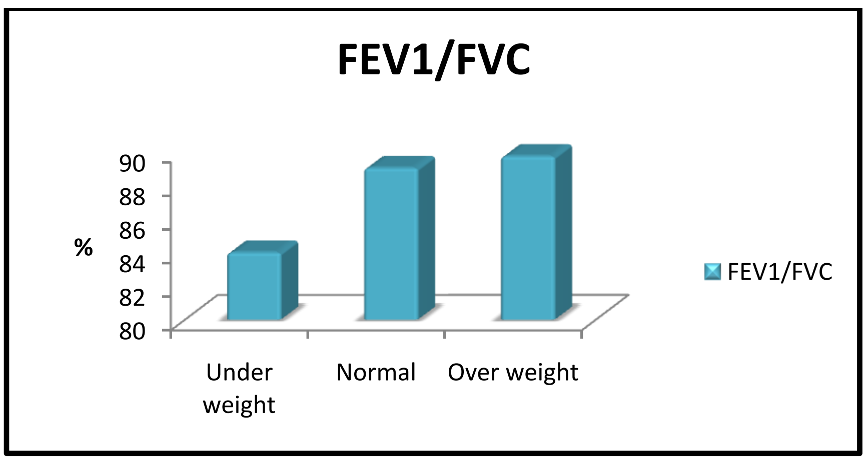


Table -10 & Chart -7 shows the distribution of FEV1/FVC in different categories of BMI .When compared to normal weight group ,it was found that there was an increase in the mean value of FEV1/FVC in overweight group (89.73± 10.49) and a decrease in mean value of FEV1/FVC in underweight group (84±15.67) . It was not statistically significant.

Table -11. Comparison of Peak Expiratory Flow among Underweight , Normal & Overweight.

Group	Mean ± SD	95% CI	P-Value
Underweight	7.46 ± 2.25	7.178 to 7.934	0.734
Normal	7.77 ± 1.95		
Overweight	7.44 ± 1.85		

*p value<0.05, ** p value <0.01, *** p value <0.001

Chart - 8. Comparison of Peak Expiratory Flow among 3 groups of BMI

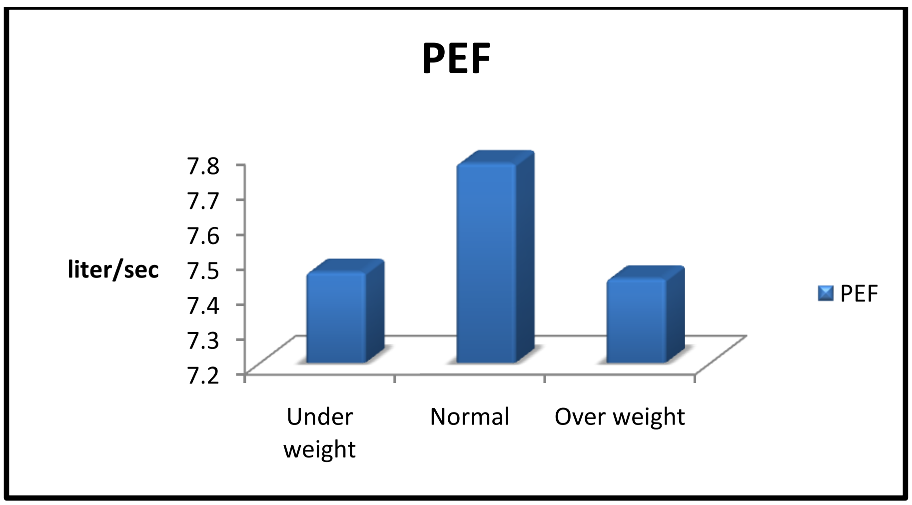


Table -11 & Chart -8 shows the distribution of Peak Expiratory Flow in different categories of BMI .The measured mean value of PEF was found to be decreased in both underweight group (7.46 ± 2.25 litre/sec) & overweight group (7.44 ± 1.85 litre/sec) when compared with normal subjects (7.77 ± 1.95 litre/sec). It did not show any significance (p = 0.734).

Table - 12. Comparison of Expiratory Reserve Volume among Underweight , Normal & Overweight.

Group	Mean ± SD	95% CI	P-Value
Underweight	1.24 ± 0.50	1.234 to 1.574	0.005*
Normal	1.79 ± 1.26		
Overweight	1.18 ± 0.65		

*p value<0.05, ** p value <0.01, *** p value <0.001

Chart -9. Comparison of Expiratory Reserve Volume among 3 groups of BMI

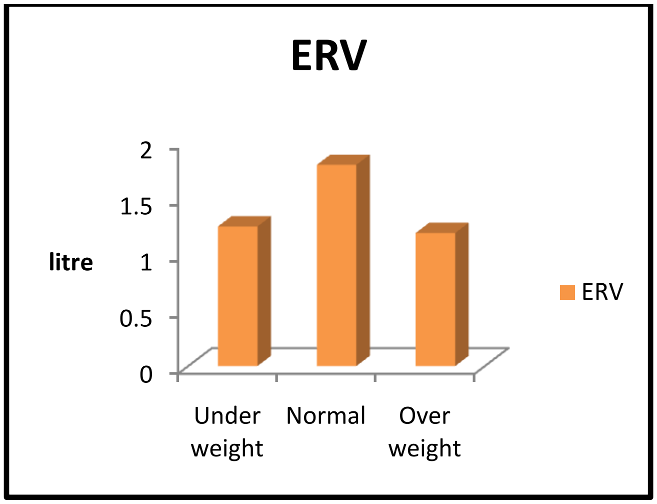


Table-12 & Chart -9 shows the distribution of expiratory reserve volume in different categories of BMI. The observed mean value of ERV was found to be reduced in underweight group (1.24 ± 0.50 litre) & overweight group (1.18 ± 0.65 litre) when compared with normal group (1.79 ± 1.26 litre).It shows a highly significance (p =0.005).

Table -13. Comparison of Maximum Voluntary Ventilation among under Weight , Normal & Overweight.

Group	Mean ± SD	95% CI	P-Value
Underweight	114.16 ± 17.09	112.144 to 122.432	0.09
Normal	125.26 ± 23.20		
overweight	112.44± 36.81		

*p value<0.05, ** p value <0.01, *** p value <0.001

Chart -10. Comparison of Maximum Voluntary Ventilation among 3 groups of BMI

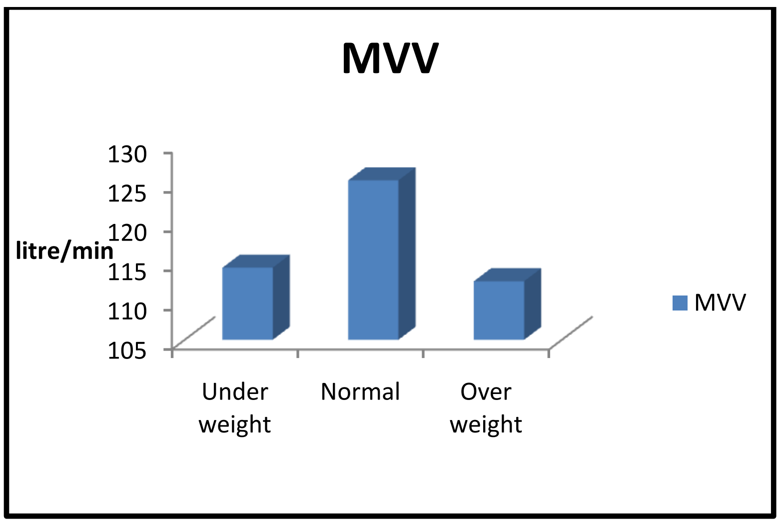


Table-13 & Chart -10 shows the distribution of Maximum Voluntary Ventilation in different categories of BMI .The observed mean value of MVV was found to be decreased in both underweight (114.16 ± 17.09 litre /min) & overweight group (112.44± 36.81litre /min) when compared with normalweight group (125.26 ± 23.20 litre /min).It did not show any statistically significance (p = 0.09).

Table -14. Comparison of Maximum Inspiratory Pressures among under weight , normal & overweight.

Group	Mean ± SD	95% CI	P-Value
Underweight	37.89 ± 18.56	33.27 to 40.66	0.722
Normal	34.84 ± 23.59		
Overweight	38.22± 16.74		

*p value<0.05, ** p value <0.01, *** p value <0.001

Chart -11. Comparison of Maximum Inspiratory Pressures among 3 groups of BMI

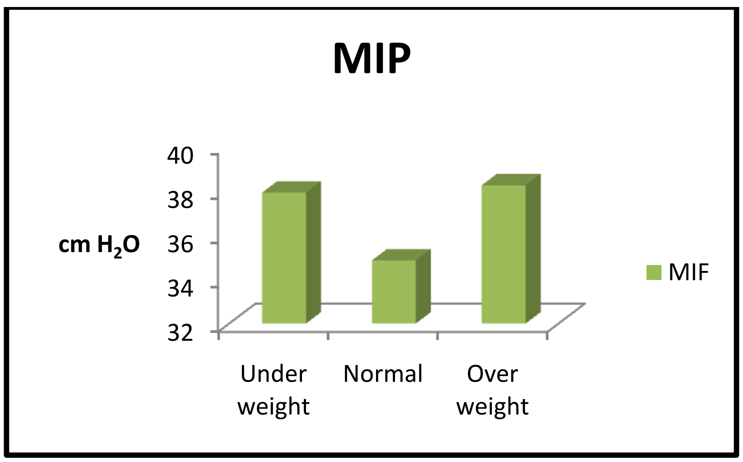


Table-14 & Chart -1**1** shows the distribution of Maximum inspiratory pressures in different categories of BMI . Minimal increase in Maximum Inspiratory Pressures were observed in underweight (37.89 ± 18.56) than overweight group (38.22± 16.74) when compared with normal group (34.84 ± 23.59). It was not statistically significant (p = 0.722) .

Table -15. Comparison of Maximum Expiratory Pressures among underweight , normal & overweight.

Group	Mean ± SD	95% CI	P-Value
Underweight	36.11 ± 13.94	30.91 to 36.66	0.491
Normal	33.32 ± 16.85		
Overweight	31.92 ± 15.05		

*p value<0.05, ** p value <0.01, *** p value <0.001

Chart -12. Comparison of Maximum Expiratory Pressures among 3 groups of BMI

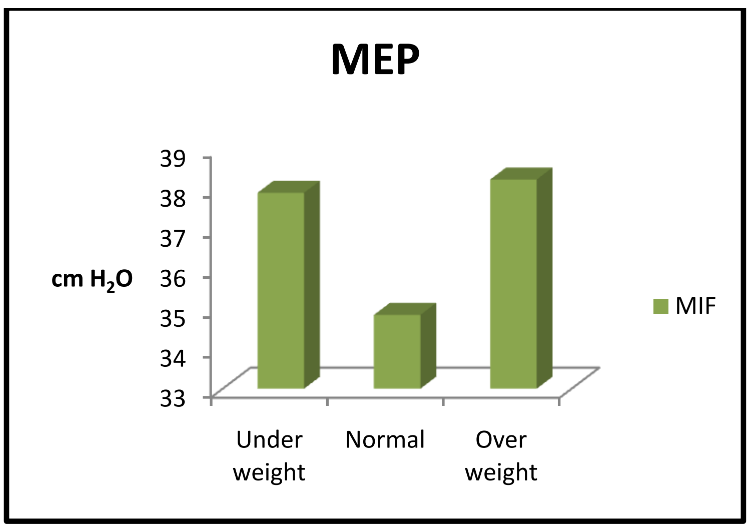


Table-15 & Chart -12 shows the pattern of distribution of Maximum Expiratory pressures in different categories of BMI. When compared with normal group, Maximum Expiratory Pressures were increased in underweight (36.11 ± 13.94 cm H_2O) & decreased in overweight group (31.92 ± 15.05 cm H_2O) .It did not show any significance (p = 0.491) .

Table-16. Correlation between normal weight & pulmonary function test

BMI	Pulmonary Parameters	Correlation Coefficient ('r' Value)	P value	Interpretation
Normal weight	**FEV1**	0.06	0.724 (NS)	Positive correlation
	FVC	- 0.13	0.443 (NS)	Negative Correlation
	FEV1/FVC	- 0.07	0.659 (NS)	Negative Correlation
	PEF	0.19	0.262 (NS)	Positive Correlation
	MVV	- 0.27	0.103 (NS)	Negative Correlation
	MIP	- 0.21	0.208 (NS)	Negative Correlation
	MEP	- 0.11	0.507 (NS)	Negative correlation

NS- non significant

Table 16 shows the Pearson's correlation between normal weight and spirometric parameters . As per the correlation table, normal weight group showed a mild positive correlation with **FEV1** (r = 0.060) and **PEF** (r=0.189) which was not significant. There was a mild negative correlation with **FVC**(r = -0.130), **FEV1/FVC**(r = -0.075), **MVV** (r=-0.272), **MIF** (r=-0.212) and **MEF** (r=-0.113) in normal weight group .

Table -17. Correlation between underweight & pulmonary function test

BMI	Pulmonary Parameters	Correlation Coefficient ('r'Value)	P value	Interpretation
Under weight	FEV1	- 0.10	0.528 (NS)	Negative correlation
	FVC	- 0.14	0.408 (NS)	Negative Correlation
	FEV1/FVC	0.162	0.339 (NS)	Positive Correlation
	PEF	0.249	0.137 (NS)	Positive Correlation
	MVV	0.11	0.518 (NS)	Positive Correlation
	MIP	0.276	0.098 (NS)	Positive Correlation
	MEP	0.298	0.073 (NS)	Positive correlation

NS- non significant

Table 17 shows the Pearson's Correlation between under weight and spirometric parameters. As per the correlation table, underweight group showed a mild positive correlation with **FEV1/FVC** (r=0.162), **PEF**(r=0.249), **MVV**(r=0.11), **MIF**(r=0.276) and **MEF**(r=0.298), but was not significant. A mild negative correlation was observed with **FEV1** (r = -0.107) and **FVC** (r = 0.140) in underweight group which was not significant.

Thus the following findings were observed after correlating the spiromtric parameters with underweight group.

1. The spirometric parameters such as the ratio of Forced Expired Volume at first second & Forced Vital Capacity, peak expiratory flow, Maximum Voluntary Ventilation, respiratory muscle strength parameters such as Maximum Inspiratory & Expiratory Pressures were found to be increased in underweight group.
2. Forced expired volume at first second and Forced Vital Capacity are the lung compliance parameters were found to be decreased in underweight group.

Table -18. Correlation between overweight & pulmonary function test

BMI	Pulmonary parameters	Correlation coefficient ('r' value)	P Value	Interpretation
Over weight	**FEV1**	- 0.05	0.782 (NS)	Negative correlation
	FVC	0.02	0.887 (NS)	Positive Correlation
	FEV1/FVC	0.16	0.407 (NS)	Positive Correlation
	PEF	0.06	0.71 (NS)	Positive Correlation
	MVV	0.13	0.452 (NS)	Positive Correlation
	MIP	0.23	0.119 (NS)	Positive Correlation
	MEP	- 0.02	0.963 (NS)	Negative correlation

NS- non significant

Table 18 shows the Pearson's correlation between overweight and spirometric parameters. As per the correlation table, a mild positive correlation was observed with **FVC** (r = 0.025), **FEV1/FVC** (r=0.160), **PEF** (r=0.061), **MVV** (r=0.137), **MIF** (r=0.237) in overweight group , which was not significant . And a negative correlation was observed with **FEV1** (r = -0.059) and **MEF** (r=-0.026) in overweight group, which was also not significant.

Thus the following findings were observed after correlating the spirometric parameters with overweight group.

1. The spirometric parameters such as Forced Vital Capacity, Peak Expiratory Flow, Maximum Voluntary Ventilation, Maximum Inspiratory Pressure were found to be increased in overweight group.

2. The lung compliance parameter Forced Expired Volume at first second and respiratory muscle strength parameter Maximum Expiratory Pressure were found to be decreased in overweight group.

3.

Table-19. One Way ANOVA -Between BMI & Spirometric Parameters

Parameters	Groups	Mean	S.D	F Value	P value
FEV1	Under weight (N = 37)	3.1551	1.07273	6.309	**0.003****
	Normal weight (N = 37)	3.8376	0.71331		
	Over weight (N=37)	3.6562	0.7339		
FVC	Under weight (N = 37)	3.5822	0.88791	1.932	**0.15**
	Normal weight (N = 37)	3.543	1.00952		
	Over weight (N=37)	3.2281	0.59756		
FEV1/FVC	Under weight (N = 37)	84	15.668	2.139	**0.123**
	Normal weight (N = 37)	89.03	12.296		
	Over weight (N=37)	89.73	10.492		
PEF	Under weight (N = 37)	7.4592	2.24711	0.31	**0.734**
	Normal weight (N = 37)	7.77	1.94562		
	Over weight (N=37)	7.4405	1.85065		
ERV	Under weight (N = 37)	1.2414	0.49627	5.486	**0.005****
	Normal weight (N = 37)	1.7895	1.26435		
	Over weight (N=37)	1.1835	0.64641		
MVV	Under weight (N = 37)	114.16	17.0882	2.46	**0.09**
	Normal weight (N = 37)	125.26	23.198		
	Over weight (N=37)	112.44	36.8121		
MIP	Under weight (N = 37)	37.89	18.562	0.327	**0.722**
	Normal weight (N = 37)	34.84	23.586		
	Over weight (N=37)	38.22	16.738		
MEP	Under weight (N = 37)	36.11	13.94	0.716	**0.491**
	Normal weight (N = 37)	33.32	16.846		
	Over weight (N=37)	**31.92**	**15.054**		

***p value<0.05, ** p value <0.01, *** p value <0.001**

Table-19 shows the relationship between BMI and spirometric parameters. As per the one way ANOVA table , a statistically significant difference was observed with Forced expiratory volume at first second (p = 0.003) and Expiratory Reserve Volume (p =0.005) between underweight, normal and overweight groups. There was no difference observed with FVC (p = 0.15), FEV1/FVC(p=0.12),PEF (p=0.73),MVV(p=0.90),MEP(P=0.49 & MIP (p=0.722) among different categories of BMI.

Table-20. Post Hoc Tests

Tukey HSD- Multiple Comparisons				
Dependent Variable	**Group-2 (I)**	**Group-1 & 3 (J)**	**Mean Difference (I-J)**	**Significance**
FEV1	Normal Weight	Under Weight	0.68243*	**0.002**
		Over Weight	0.18135	**0.634**
ERV	Normal Weight	Under Weight	0.54811*	**0.021**
		Over Weight	0.60595*	**0.009**

Table-20 shows the turkey post hoc test for forced expiratory volume at first second (FEV1) & Expiratory reserve volume (ERV) among underweight, normal weight and overweight groups.

- FEV1 revealed that the forced expiratory volume at 1 sec in litre was significantly decreased in underweight group (3.15 ± 1.07 litre) but not in overweight group (3.66 ± 0.73 litre) when compared to normal weight group (3.84 ± 0.71 litre).
- ERV was significantly decreased in underweight group (1.24 ± 0.49 litre) and overweight group (1.18 ± 0.65 litre) when compared to normal weight group (1.79 ± 1.26 litre).
- There was no significant difference among different categories of BMI with Forced Vital Capacity (p =0.15), FEV1/FVC(p = 0.12), Peak Expiratory Flow(p=0.73), Maximum Voluntary Ventilation (p=0.90), Maximum Inspiratory Pressures (p=0.722) and Maximum Expiratory Pressure (p=0.491).

DISCUSSION

This study was conducted in male medical students in 3 different categories of BMI such as underweight, normal & overweight. Only very few comparative studies of Pulmonary function tests were done in all 3 categories of BMI. This present study was aimed to evaluate pulmonary functions in underweight, normal & overweight groups and to correlate them with BMI. In this study pulmonary functions were assessed by the following spirometric parameters such as Forced Vital Capacity, Forced Expiratory Volume in 1 second, FEV1/FVC ratio, Peak Expiratory Flow rate, Maximum Voluntary Ventilation, Maximum Inspiratory & Expiratory Pressures. Lung functions showed a ‘U’ shaped relationship with BMI i.e lung functions are diminished in both underweight and obese when compared to normal.

Relation between BMI and Forced vital capacity (FVC):

Present study showed no significant difference in forced vital capacity in all 3 groups of BMI. This result is contradictory to the Study done by SUDHIR et al in south Indian males in the age group 30 and above yrs, as they found that FVC was significantly increased as BMI increased suggesting the emphysematous changes in overweight group.[9] But our study was done in young adults males in the age group 18-19 yrs .This difference in the age group of the study subjects could be the reason for the variation in the results.

A Cross sectional Study was done by Ahamed Azad et al in sedentary young female adults, showed a significant reduction in FVC and it was positively correlated with underweight group when compared with normal weight group[16]. In our study, FVC showed no significant correlation with underweight group in the young adult males, which is contradictory to previous study. The volume of female lung is 10-12% smaller than that of males of same range, height and age[13]. Females tend to have lower pulmonary function test values when compared to males due to decreased respiratory muscle endurance & chest wall compliance[28] .This could be the reason for the contradicting result in our study.

Relationship between BMI and Forced Expiratory Volume in First second (FEV_1):

FEV_1 is the forced expiratory volume in the first second in which 80 to 85% of forced vital capacity is expired normally in the first second. It is one of the useful parameters to detect the generalized airway obstruction.[4] Adiposity in the chest wall and abdomen was considered to restrict the movement of chest and diaphragm.[13] In our study, we found significant reduction in FEV_1 in underweight than overweight group when compared with normal weight group. This is in support by study done by K.Soundarya et al .Their result showed that there was a decrease in lung volumes in underweight group than overweight when compared to normal weight subjects in 18-21 yrs age group study population.[1] This reduction in lung volumes is due to poor source of body proteins causing wasting of skeletal muscle including respiratory muscle which leads to poor respiratory strength in underweight individuals .[25]

The present study is consistent with the study done by Vijetha et al in 18-30 yrs age population, they observed that there was a significant reduction in all the pulmonary parameters such as FVC, FEV_1, FEV1/FVC, PEF in overweight subjects[4]. This reduction in the above mentioned parameters in overweight group is due to increased mass of fat in the chest and abdomen. This causes alteration in respiratory movement leading to a decrease in compliance of the respiratory system as a whole[4].

Our study results are still more strengthened by Sudhir K et al , who showed that FEV1 was significantly reduced in overweight group than normal weight in the study conducted among south Indian adult male population. [9]

Anugya Aparajitha et al conducted a study in 60 healthy subjects in the age group of 20-65 yrs age population , they found that increase in BMI decreases FEV_1 indicating a restrictive pattern of lung functions. They concluded that BMI independently affects pulmonary function & the correlation pattern was different for males & females.[79] Our study also showed decreased FEV1 in overweight population which is consistent with the above mentioned study.

A cross sectional study conducted on Gujarat Indian adolescent boys of age group 17-21 yrs by HASMUK Shah et al showed that underweight boys had reduced dynamic lung parameters (FEV_1, FEV_6, PEFR) when compared to normal weight boys. This is consistent with our study, which showed a similar reduction in FEV_1 except PEFR in underweight group when compared to normal weight group.[6]

Similar type of reduction in FEV_1 was seen in the overweight group in the study by Kalpojit Saikia et al among MBBS & postgraduate student in the age group of 20-29 yrs in Silchar Medical College.[12] This result supports our study. But study conducted by Saikia et al showed a significant negative correlation of BMI with FVC & FEV1 which is contradicting our result. Another study which also showed a reduction in FEV1 in both underweight and overweight group by Umesh Pralhadrao et al [86] supports our study. They also found reduction in FVC & $FEF_{25-75\%}$ which is not consistent with our result. Our study is partly supported by Sohail Attaur et al, who showed similar type of reduction in FVC & FEV1 and negative correlation of

BMI with FVC & FEV1 in overweight group like the previous mentioned study of Kalpojith Saikia.[87]

A Cross sectional study done by Mohamed Ai Ghlobain et al in Saudi Arabia population among healthy non smoking adults, showed that obesity does not have effect on the spirometry tests (except PEF).[26] But our study done in South Indian adult males showed a decrease in PEF in both underweight and overweight group when compared to normal, however the results were not significant .This could be due to ethnic difference which could influence the pulmonary function test.[26] G. Linyanage et al did a cross sectional study among 275 school children in the age group of 9-15 yrs in Srilanka and they found that dynamic lung function was reduced in normal subjects.[88] But in our study it was found that FEV1 and ERV were reduced in underweight and overweight group compared to normal group. In our study the subjects were between 18 to 19 yrs. Age could influence the pulmonary function which might be the reason for the contradicting result in our study.

Relationship between between BMI and FEV_1/FVC ratio:

FVC and FEV_1 are strong indicators of lung function which decrease due to sedentary life style.[16] FEV_1/FVC ratio is called as Tiffeneau - Pinelli Index. This calculated ratio represents the proportion of person's vital capacity that an individual can expire in the first second of expiration. It is a useful test to differentiate obstructive and restrictive lung disease. Restrictive lung disease like lung fibrosis & physical deformity is characterized by low FVC but normal FEV_1/FVC ratio, whereas obstructive lung disease like asthma, bronchitis or emphysema is characterized by low FEV1 and low FEV_1/FVC ratio.[86]

Our study showed no significant difference in FEV_1/ FVC ratio in all 3 categories of BMI. This was contradictory to the study of Joyarani Devershetty et al who did a cross sectional study among 60 healthy young female subjects, showed a significant difference in FEV1/FVC ratio & PEFR without compromising other lung functions.[27] This may be due to influences of gender on pulmonary function test.

Dharmendra Dodiya et al did a correlation study in 198 male subjects in the age group of 20 to 45 yrs. Their result showed a significant positive correlation of BMI with FEV1/FVC & showed a negative correlation of FEV1 with BMI [89] but our study showed no significant correlation between all categories of BMI. This may be due to dominant effects of increasing BMI on diaphragmatic limitations or chest wall restrictions.

Relationship between BMI and Peak Expiratory Flow (PEF):

PEF is an expiratory parameter to measure the caliber of the airways. It is used as a bedside screening method to diagnose the presence of airflow limitations and to assess the variations & severity. Our study showed a decrease in PEFR which was not statistically significant among underweight and overweight group when compared to normal group. This was in contrast to study conducted by BROSE.LJ et al on 121 first year students of DUPMC college in the age group of 18-22 yrs, their results showed a significant decrease in PEF in overweight group than underweight group. PEF is affected by expiratory muscle strength, elastic recoil of the lungs & airway size. Reduction in PEF in overweight is due to fat distribution between the muscle and ribs which causes increase in the metabolic demand & work of breathing[3] and reduction in PEF in underweight is due to reduced respiratory muscle mass & diaphragmatic muscle mass which impairs ability to generate inspiratory force [85] as quoted by previous studies.

Our result is partly supported by another study conducted in 120 medical students in both males and females in the age group of 18-25 yrs by Suganya et al , their result showed that PEF was significantly reduced in females than males in both underweight and overweight group . They also explained that low & high BMI results in poor lung function which occurs in combination of airway narrowing & decreased lung recoil.[78]

Jenan Hussein Taha et al found no significant difference in PEF in overweight & obese in both males and females Iraq population. They found significant difference between men and women of all ranges of BMI. This result supports our study, we also found no significant difference in PEF in both underweight & overweight group when compared to normal group adult males.[13]

Study done by Walaa et al showed a contradictory result of significant reduction of PEF in high BMI group when compared to normal BMI group in both male and female in Iraq population.[90] Difference in the ethnicity of the study subjects could be the reason for the contradicting results in our study.

According to Dr.Shinde et al, they had similar result of significant decrease in FEV1 & non significant difference in FEV1/FVC, PEF,MEF in overweight group when compared to normal weight like our study. But decrease in FVC in overweight was contradictory to our result.[80]

Kohli PG etal analyzed the relationship between pulmonary function test and body mass index in18 to 25 yrs old Punjabi youngster population .They found that FVC,PEF & MVV is decreased more in female than males in both underweight & overweight BMI .This does not support our results.[82]

Relationship between BMI and Expiratory Reserve Volume (ERV)

FRC and ERV are the most important parameters which are decreased in obesity and detectable even at mild increase in weight.[39] The presence of adipose tissue around rib cage, abdomen and in the visceral cavity causes reduction in the functional residual capacity (FRC) [14]**.** Study conducted by Ashvin Sorani et al in 140 medical students in the age group of 18-24 yrs showed that increase in BMI decreases ERV. They also showed that there was no significant correlation of BMI with IC, FEV1 / FVC, MVV, PEFR. This result was not consistent with our study. Similar type of result was also obtained by other study done by Ray Cs et al.[45]

Relationship between Maximum voluntary ventilation (MVV):

MVV maneuver represents the integration of many factors in the pulmonary mechanics such as endurance, airway diameter, respiratory muscle strength and it is also related to chronic airway obstruction.[88] We found no significant difference in MVV in all 3 categories of BMI.

Our result was contradictory to W.LADOSKY et al, who proved that MVV reduces as BMI increases, which results in the reduction of FEV1. FEV1 reduction in proportion to FVC suggests the burden on chest wall by increased adipose tissue resulting in low static volumes and flows.[88]

CONCLUSION

Obesity is a major health problem worldwide, which is associated with increased mortality and morbidity.[90] Obesity is defined as excess or abnormal accumulation of adipose tissue in the body.[93] Upper body obesity usually results in reduction in lung volumes and compliance.[11] Obesity was categorized on the basis of Body Mass Index & pulmonary function tests were performed in all 3 categories of BMI. Pulmonary functions were correlated with different groups of BMI. It was found that ERV is significantly decreased in overweight group. In obese individual reduction in ERV is due to deposition of adipose tissue in the chest wall and abdominal areas which increases the intra-abdominal pressure causing mechanical restriction of the movement of the chest and diaphragm.[81] Our study showed a decrease in FEV1in underweight group which was significant. Decrease in FEV1 (dynamic lung function) is an obstructive type of dysfunction. We also observed a decrease in Expiratory Reserve Volume (static lung functions) in underweight group. From the above finding we can conclude that underweight group had disturbance in ventilator mechanics. Poor respiratory muscle strength due to poor respiratory and diaphragmatic muscle mass causes reduction in lung volume in underweight group.[6]

It is concluded in the study that static lung function (ERV) is altered in overweight group and underweight group. Dynamic lung function (FEV1) is reduced in underweight group. Thus we conclude that the body mass index must be within normal limits for optimal respiratory function.

SUMMARY

A cross sectional study was conducted in 111 male medical students and they were categorized into 3 groups according to BMI (37 in each group –underweight, normal & overweight). The parameters used to assess the pulmonary functions were FVC, FEV1, FEV1/FVC, PEF, MVV, ERV, MEP & MIP. The result showed a statistically significant ($p<0.05$) decrease in pulmonary functions particular FEV1 and ERV. Forced expiratory volume in one second is significantly reduced more in underweight than overweight group. Expiratory reserve volume is decreased in both underweight and overweight group when compared to normal group. This study showed that pulmonary functions were affected at both extremes of BMI. And mild obstructive type of pulmonary defect was found in underweight group when compared to other 2 groups of BMI. Deposition of adipose tissue in the chest and abdomen causes restriction of the movements of the chest which leads to reduction in lung volume in obese individual.[13] Reduction in lung volumes in underweight individual is due to poor respiratory muscle strength.[25]

LIMITATIONS OF THE STUDY

1. The sample size was small
2. It was a cross –sectional study
3. This was a small group which was carried out in single institute.
4. Various age groups & females were not included in the study
5. Comparisons between measured & predicted values were not done.
6. Grading of FVC, FEV1 & FEV1/FVC ratio was not done.
7. DLCO which was done in previous studies was not included in this study.

RECOMMENDATIONS

- This study should be conducted with larger sample size with wider age groups along with gender matched for better results.
- A longitudinal study will definitely be of a greater value in predicting the relationship between pulmonary parameters and BMI
- Following suggestion & recommendation should be given for the prevention & control of overweight & obesity.
- Consumption of low calorie diet should be advised in obese individual.
- Plans to lose weight like daily walking, exercise, avoiding oily foods, once a week fasting should be followed.
- Awareness to maintain BMI within normal level by life style modifications and intervention might help in moving forward for eradication of obesity and impairment of pulmonary functions.

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PROFORMA

1.Name:

2.Age:

3.Day Scholar/Hostellite:

4.Year Of Study:

5.Name Of The Institution:

6.Diet History:

- ❖ Veg /Non Veg:
- ❖ Are You On Any Kind Of Diet Regimen:

7.Personal History:

- ❖ H/O Of Smoking/Drug Abuses:
- ❖ H/O Diabetic /Hypertension:
- ❖ H/O Any Respiratory Illness:
- ❖ Have You Been On Medication For Any Medical Illness?
- ❖ H/O Any Physical Activity:

8.Socio Economic Status:

9.Family History:

Is Any Of Your Parents Are Hypertensive /Diabetic/Have Respiratory Illness

If So ,Specify:

Anthropometric Parameters:

- Height:
- Weight:
- Waist Circumference:
- Hip Circumference:

To Be Filled By The Investigator:

- BMI:
- Waist /Hip Ratio:

Physiological Parameters:

- Respiratory rate:
- Pulse rate:
- Blood pressure:

Spirometry Findings:

- ❖ FVC-Forced Vital Capacity:
- ❖ FEV1-Forced Expiratory Volume at 1second:
- ❖ SVC-Slow Vital Capacity:
- ❖ MVV-Maximum Voluntary Ventilation:
- ❖ MIP-Maximum Inpiratory Pressure:
- ❖ MEP- Maximum Expiratory Pressure:
- ❖ VC-Vital Capacity:
- ❖ ERV-Expiratopry Reserve Volume:
- ❖ VT –Tidal Volume

Trichy SRM Medical College Hospital & Research Centre, Irungalur,Trichy-621 105.

CONSENT FORM

You are requested to participate in a study conducted in the Department of Physiology, Trichy SRM Medical College Hospital & Research Centre, Irungalur, Trichy.

Titled -**"Comparing Effects Of Lung Function Test On BMI"**

- Your participation in this study is voluntary.
- Your participation is not a compalsion.
- You have the right to withdraw from the study at any time.
- There will be no cost for participating in this study.

EXPLANATION OF PROCEDURES:

If you agree to participate in this study,you are expected to fill out self-administered questionnaires and we would collect relevant information with a series of easy tasks.Data from the study will be used for research purpose only.

ASSURANCE OF CONFIDENTIALITY:

The information concerning your participation in this study will be kept confidential to the full extend permitted by law and used only for scientific purpose.No one except members of the research team will have acces to the results.

We believe that the results of **this study will be beneficial for advancements in medical science.**

PARTICIPANT CONSENT:

I Mr ________________residing at___________________ have read the explanation about this study and give my consent for participating in this study and for using the results for medical and scientific purposes

Signature of Subject

Date:

Signature of Researcher

(DR.Lavanya.A.V)

திருச்சி எஸ் ஆர் எம் மருத்துவக் கல்லூரி மருத்துவமனை மற்றும் ஆராய்ச்சி மையம்

இருங்களூர் திருச்சிராப்பள்ளி – 621105

ஒப்புதல் படிவம்

திருச்சி எஸ் ஆர் எம் மருத்துவக் கல்லூரி மருத்துவமனை மற்றும் ஆராய்ச்சி மையத்தின் உடலியல் துறையில் நடத்தப்படும்.**"நுரையீரல் செயல்பாடு சோதனை உடல் நிறை குறியீட்டெண் குறித்து ஒரு ஒப்பீட்டு ஆய்வு"** பங்கேற்குமாறு **உங்களை கேட்டு கொள்கிறேன்**.

- இப்பரிசோதனைக்கு சம்மதிப்பது உங்கள் விருப்பத்தைப் பொறுத்தது.
- கட்டாயம் ஏதும் இல்லை.
- பரிசோதனையிலிருந்து எந்தநேரமும் விலக தங்களுக்கு முழு உரிமை உண்டு.
- இச்சோதனைக்கு கட்டணம் கிடையாது.

இந்த ஆய்வின் முடிவுகள் மருத்துவம் மற்றும் ஆராய்ச்சி முன்னேற்றத்திற்கு உதவும் என்று கருதுகின்றோம். இவைகளை வேறு எதற்கும் பயன்படுத்தப்பட மாட்டாது என உறுதியளிக்கிறோம்.

ஒப்புதல்

நான் திரு……………………………..…….முகவரி……………நாள் ……………அன்று மேற்கண்ட ஆய்வுக்காக தகவல் படிவத்தினை படித்து கேட்டு புரிந்து கொண்டு இந்த ஆராச்சிக்கு என் மனப்புர்வமான சம்மத்தை அளிப்பதோடு இந்த ஆய்வின் முடிவுகளை மருத்துவம் மற்றும் ஆராச்சி நோக்கத்திற்கு பயன்படுத்த ஒப்புதல் அளிக்கிறேன்.

பங்கேற்பாளர் கையொப்பம்

ஆய்வாளர் சம்மதம்

பெறுபவர் கையொப்பம்

KEY TO MASTER CHART

INDEX	Meaning
HT	Height
WT	Weight
BMI	Body Mass Index
WC	Waist Circumference
HC	Hip Circumference
WHR	Waist Hip Ratio
FEV1	Forced Expiratory Volume At First Second
FVC	Forced Vital Capacity
PEF	Peak Expiratory Flow
SVC	Slow Vital Capacity
ERV	Expiratory Reserve Volume
MVV	Maximum Voluntary Ventilation
MIP	Maximum Inspiratory Pressure
MEP	Maximum Expiratory Pressure

UNDERWEIGHT GROUP

S/No	NAME	Age/Sex	HT	WT	BMI	WC	HC	WHR	FEV1	FVC	FEV1/FVC	PEF	SVC	ERV	MVV	MRF	MVT	MVVT	MIF	MEF
1	Aneeshraj	18/M	180	53	16.36	71	71	1.00	3.82	4.16	108	8.34	2.10	1.44	137.9	107.5	1.28	12.29	27	43
2	Akilesh	18/M	180	51	15.74	66	88	0.75	3.05	4.22	72	3.89	3.20	0.91	120.3	54.5	2.34	10.99	9	13
3	Hariprasad	18/M	165	50	18.37	66	88	0.75	2.28	2.32	98	9.32	1.83	2.12	113.0	111.9	1.33	12.33	14	31
4	Harishkumar	18/M	183	54	16.12	77	92	0.84	3.07	5.39	56	3.02	2.98	1.21	115.2	103.9	1.17	4.62	36	13
5	Raguvamsikrishna	19/M	178	48	15.15	83	95	0.87	2.95	4.38	67	4.50	3.50	1.03	137.0	113.2	1.11	11.67	17	16
6	Rajkumar	18/M	184	60	17.72	74	95	0.78	2.49	3.78	65	7.23	4.56	1.35	114.0	68.1	1.65	11.45	28	21
7	S.Elanthamilan	19/M	172	51	17.24	78	95	0.82	2.59	3.34	77	8.20	6.23	0.90	109.0	81.8	1.21	11.00	24	17
8	Varunraj	18/M	175	56	18.29	75	95	0.79	3.27	3.65	89	9.10	7.32	1.23	124.0	63.0	1.56	11.42	15	17
9	Shan Siddharath	18/M	167	50	17.93	63	85	0.74	2.56	2.35	108	10.2	5.23	1.12	126.5	43.2	2.68	11.11	89	41
10	Kishore	18/M	172	50	16.90	66	80	0.83	2.84	2.84	99	9.90	2.40	1.54	103.0	55.9	1.85	10.73	16	21
11	Saran Adithya	18/M	178	56	17.67	66	82	0.80	2.99	3.44	86	7.93	1.62	0.91	101.7	117.1	0.81	11.79	59	33
12	Samual Jesuram	18/M	174	54	17.84	63	85	0.74	3.34	3.43	97	4.44	3.22	2.13	122.5	54.9	2.23	10.91	75	60
13	Vishwak	19/M	167	52	18.65	77	92	0.84	2.30	2.69	85	5.59	1.59	1.22	109.5	74.6	1.47	12.06	31	39
14	S.Karthikeyan	18/M	175	55	17.96	77	90	0.86	3.50	3.99	87	8.34	2.21	0.48	88.3	43.3	2.04	9.70	22	33
15	S.Prithviraj	18/M	178	56	17.67	66	78	0.85	3.53	4.13	85	5.07	1.85	0.74	120.3	68.5	1.76	10.50	31	43
16	S.Kumar	18/M	178	52	16.41	83	90	0.92	3.40	3.40	99	10.36	1.76	0.76	114.5	77.6	1.48	10.83	48	37
17	S.Mukeshraj	18/M	168	51	18.07	74	95	0.78	2.27	2.66	85	3.99	3.41	2.13	112.1	99.0	1.13	12.12	57	52
18	S.Harish	18/M	168	52	18.42	63	85	0.74	4.23	4.67	90	9.46	2.24	1.35	114.8	68.7	1.67	11.35	35	42
19	Bharathchander	18/M	173	50	16.71	66	85	0.78	8.57	3.28	38	4.44	3.47	1.85	133.2	89.8	1.48	10.69	43	24
20	Sivaharan	19/M	168	52	18.42	83	95	0.87	3.01	3.17	81	10.9	1.92	1.22	142.4	73.8	1.93	11.39	61	48
21	Suresh	18/M	183	49	14.63	77	85	0.91	2.30	2.52	85	4.24	1.64	1.05	77.1	119.5	0.65	4.02	51	45
22	Jeyaprakash	18/M	171	50	17.10	63	85	0.74	2.03	3.07	66	9.21	1.63	1.13	118.0	80.5	1.48	11.98	53	43
23	Vinodh	19/M	178	56	17.67	72	72	1.00	2.28	2.32	98	10.38	5.53	2.42	110.3	133.3	0.83	12.17	49	35
24	Surender	19/M	167	50	17.93	63	85	0.74	3.31	3.55	93	8.30	2.53	1.52	115.2	55.9	2.06	9.66	35	34
25	Bibin Joseph	18/M	176	54	17.43	66	88	0.75	3.43	6.05	56	5.70	7.80	1.30	105.5	99.5	1.06	11.47	24	15
26	Karthikeyan	19/M	174	55.5	18.33	74	95	0.78	2.83	3.91	72	8.30	0.96	0.23	134.6	74.4	1.81	11.29	35	28
27	Harish	18/M	178	56	17.67	66	82	0.80	2.99	3.44	86	7.93	1.62	0.91	101.7	117.1	0.81	11.79	59	33
28	Suresh.R.A	18/M	182.4	49	14.73	66	88	0.75	3.50	3.99	87	8.34	2.21	0.48	88.3	43.3	2.04	9.70	16	24
29	Velmurugan	19/M	175.5	55	17.86	75	95	0.79	2.99	3.44	86	7.93	1.62	0.91	101.7	117.1	0.87	11.79	13	48
30	Ram Mugesh	18/M	174.5	48	15.76	83	95	0.87	2.84	2.84	99	9.90	2.40	1.54	126.5	55.90	1.85	10.73	20	54
31	Mukesh Raj	18/M	176	56	18.08	63	85	0.74	3.82	4.16	91	6.55	2.44	1.44	137.9	107.5	1.28	12.29	46	52
32	Sivaram	19/M	170	52	17.99	75	95	0.79	2.30	2.69	89	5.54	1.59	1.22	109.5	74.6	1.47	12.06	40	34
33	Jarim Danial	19/M	164	48	17.85	66	78	0.85	3.07	5.39	56	9.80	2.40	1.54	127.5	59.9	1.85	11.11	34	28
34	Nagendra Raju	18/M	168	52	18.42	83	90	0.92	3.31	3.55	93	8.30	2.53	1.52	115.2	55.9	2.06	9.66	40	52
35	Vignesh .S	19/M	178	56	17.67	61	61	1.00	3.82	4.16	91	6.55	2.44	1.44	137.9	107.5	1.28	12.29	50	60
36	Venkatesa Prasad	19/M	168	52	18.42	74	90	0.82	2.05	2.32	88	5.20	0.97	0.32	75.3	121.4	0.62	5.92	60	52
37	Senjudar	18/M	169	50	17.51	68	70	0.97	3.81	3.85	99	9.60	1.90	1.32	82.5	85.8	0.99	11.89	40	55

NORMAL GROUP

S/No	NAME	Age/Sex	HT	WT	BMI	WC	HC	WHR	FEV1	FVC	FEV1/FVC	PEF	SVC	ERV	MVV	MRF	MVT	MVVT	MIF	MEF
1	Angu Naveen	18/M	170	61	21.11	91	81	1.12	3.70	3.06	82	4.33	2.27	1.58	143.6	95.3	2.26	11.89	51	62
2	Akash	19/M	174	68	22.46	98	84	1.17	3.24	3.25	99	8.42	3.24	1.22	151.7	59.4	2.19	12.11	15	17
3	Bharathchandar	18/M	173	62	20.72	71	90	0.79	4.71	4.90	92	7.36	4.03	2.07	123.0	68.7	1.93	11.35	56	29
4	Badrinarayanan	18/M	180	72	22.22	81	97	0.84	4.50	4.06	90	9.56	2.89	1.23	156.0	68.5	1.73	10.51	31	17
5	Sarathkumar	19/M	169	63	22.06	74	94	0.79	3.88	3.57	91	10.58	6.89	2.76	113.0	76.2	1.92	9..45	47	23
6	Sivaharicharan	18/M	182	71	21.43	71	99	0.72	3.70	3.60	98	10.90	1.92	1.15	142.4	73.8	1.76	11.21	20	17
7	Siddharath	19/M	179	67	20.91	74	104	0.71	4.14	3.42	82	8.07	3.50	1.98	140.3	74.2	1.89	8.08	19	21
8	Simel Thomas	18/M	170	64	22.15	74	93	0.80	4.71	4.90	92	9.56	4.23	3.56	156.0	56.9	1.94	10.53	30	35
9	Tharoon	18/M	171	60	20.52	77	93	0.83	3.74	3.56	95	6.36	3.96	1.94	120.8	78.8	1.53	10.66	30	56
10	Thivakar	19/M	180	62	19.14	76	92	0.83	3.88	3.57	91	8.92	3.64	1.17	131.5	75.2	1.75	11.96	22	16
11	Yaswanth	18/M	175	64	20.90	69	90	0.77	3.22	3.22	100	9.45	3.40	0.81	142.0	38.8	2.81	9.26	63	46
12	Anurag	18/M	168	54	19.13	78	89	0.88	4.71	4.90	92	8.56	4.78	2.56	142.0	136.6	1.08	7.03	17	18
13	Abisheik Mohamad	18/M	173	68	22.72	78	100	0.78	3.99	3.24	81	9.10	2.69	1.24	121.8	77.7	1.57	5.41	30	39
14	Devanand	18/M	182	76	22.94	77	101	0.76	4.50	4.06	90	8.47	2.24	1.89	124.3	106.3	1.17	11.86	26	19
15	Aswin Sriram	19/M	176	76	24.54	92	102	0.90	2.98	2.90	100	10.78	4.23	3.45	114.0	64.3	1.59	11.20	10	9
16	Dinesh Kumar	19/M	179	64	19.97	73	91	0.80	5.39	3.34	61	6.26	1.66	1.42	133.5	165.7	0.81	12.34	109	45
17	Aswanth	18/M	172	70	23.66	88	105	0.84	3.65	3.27	89	7.30	1.76	0.05	119.4	94.4	1.26	11.43	41	39
18	Dakshin	18/M	183	80	23.89	87	100	0.87	3.40	2.85	83	9.25	3.58	1.56	135.0	91.8	1.66	11.77	17	18
19	Nikil	18/M	182	72	21.74	79	95	0.83	2.98	3.25	109	7.89	3.56	0.98	142.0	108.4	1.80	10.51	30	41
20	L.Ve.Prasath	19/M	178	61	19.25	70	94	0.74	2.98	3.25	95	8.23	3.02	1.25	142.0	113.2	1.18	12.20	19	21
21	G.R.Ragul	18/M	172	72	24.34	82	96	0.85	4.71	4.90	92	10.23	4.23	2.24	115.0	105.2	1.27	9.13	12	15
22	Farhan Marook	18/M	173	65	21.72	78	93	0.84	3.86	3.10	80	10.40	2.94	2.20	146.0	117.1	1.27	11.78	21	29
23	Hari Prasad	19/M	165	54	19.83	66	88	0.75	3.74	7.69	112	8.64	3.42	1.95	92.4	111.9	1.33	12.33	20	31
24	R.Vignesh	19/M	170	64	22.15	70	94	0.74	3.34	2.59	77	4.67	1.60	0.98	93.0	92.4	1.01	11.69	21	26
25	K.Ganesh	18/M	160	60	23.44	69	70	0.99	4.71	4.90	92	7.46	3.42	2.56	73.3	83.4	0.88	10.79	17	24
26	Siddharath	19/M	179	67	20.91	74	102	0.73	4.14	3.42	98	8.70	3.50	1.98	140.3	22.0	32.00	1.40	12	15
27	Manikandan	18/M	179	64	19.97	78	88	0.89	1.91	1.84	96	4.37	2.42	1.24	86.0	57.9	1.49	10.36	81	60
28	Arihant Bohra	18/M	183	75	22.40	72	90	0.80	3.74	3.05	95	6.78	3.42	1.73	146.0	74.7	1.96	6.43	19	21
29	Kabilash	19/M	165	65	23.88	66	88	0.75	2.98	3.25	109	5.81	2.60	2.26	110.9	58.2	1.91	11.34	15	13
30	Nithish	18/M	175	69	22.53	79	95	0.83	3.78	2.49	65	5.04	3.10	0.89	90.5	63.2	1.43	11.39	98	49
31	Mohanakumar	19/M	175	70	22.86	71	90	0.79	3.96	3.94	99	8.33	3.30	0.80	99.3	103.3	0.96	11.63	55	62
32	Revin Kumar	19/M	156	50	20.55	71	98	0.72	3.22	2.56	79	4.25	2.61	1.23	109.0	114.9	0.95	120.10	38	54
33	Sanjai	18/M	173	58	19.38	80	94	0.85	3.60	3.36	93	7.33	2.15	0.99	159.5	104.7	1.52	11.47	29	26
34	Kesava Paven	18/M	175	70	22.86	81	91	0.89	3.81	2.85	74	5.94	1.24	1.02	85.0	75.1	1.13	11.18	27	57
35	Manoj.S	19/M	174	70	23.12	97	102	0.95	5.39	3.07	56	8.38	7.84	7.84	100.6	67.1	1.50	11.61	30	51
36	Angu Naveen	19/M	168	61	21.61	76	92	0.83	3.70	3.06	82	4.33	2.27	1.58	143.6	95.3	1.51	8.81	55	49
37	Jegasirpan	18/M	170	65	22.49	97	102	0.95	3.40	2.85	83	7.48	1.44	0.85	150.0	108.1	1.39	11.67	56	63

OVERWEIGHT GROUP

S/No	NAME	Age/Sex	HT	WT	BMI	WC	HC	WHR	FEV1	FVC	FEV1/FVC	PEF	SVC	ERV	MVV	MRF	MVT	MVVT	MIF	MEF
1	V.Ashok	18/M	181	103	31.44	99	120	0.83	4.22	3.05	72	6.78	3.42	0.71	131.6	73.6	2.14	10.60	43	17
2	Syed Mohammed	18/M	180	97	29.94	109	120	0.91	4.06	3.46	85	6.29	3.03	0.36	126.7	73.1	1.73	9.02	32	11
3	N.Tamilarasan	18/M	183	89	26.58	93	113	0.82	3.83	3.61	94	3.89	3.80	0.72	171.7	98.5	1.74	12.18	35	17
4	M.Vasanth	18/M	177	93	29.68	40	43	0.93	3.58	3.26	91	8.00	4.15	1.45	129.1	76.4	1.69	9.42	37	36
5	Vignesh Kumar	19/M	165	78	28.65	98	107	0.92	3.36	3.28	96	6.65	2.83	1.21	70.0	41.6	2.41	4.32	23	34
6	Ansar	18/M	182	89	26.87	96	100	0.96	3.24	3.20	98	6.34	3.36	1.96	79.0	75.4	1.90	9.10	43	17
7	Moulitharan	18/M	175	98	32.00	110	126	0.87	3.13	3.05	97	7.38	4.35	1.29	95.6	72.2	1.33	8.30	15	34
8	Manoj	18/M	182	85	25.66	97	102	0.95	3.54	3.54	100	7.86	2.40	1.44	127.0	82.9	1.35	9.67	43	18
9	Bhuvanesharan	18/M	175	107	34.94	117	123	0.95	3.72	3.71	99	8.23	2.47	0.81	150.3	67.7	2.22	8.86	35	47
10	Akash	19/M	115	90	68.05	102	117	0.87	3.24	3.20	98	8.20	3.24	1.22	151.7	121.7	1.25	11.34	73	45
11	K.Mukesh	18/M	175	88	28.73	94	111	0.85	3.56	3.13	87	9.47	3.07	0.51	62.0	91.8	1.18	11.76	20	21
12	Pragadesh	18/M	161	90	34.72	92	112	0.82	3.90	3.00	102	9.47	3.07	1.62	1.8	58.6	1.21	12.45	45	20
13	Ahamed Ali	18/M	180	90	27.78	97	109	0.89	4.45	4.37	98	10.54	4.20	1.94	84.0	99.1	1.31	12.11	19	14
14	Gowrav Rao	19/M	184	93	27.47	102	113	0.90	2.32	2.05	88	8.64	2.54	2.34	63.0	129.5	0.80	12.52	20	18
15	Asok	19/M	185	120	35.06	109	110	0.99	4.22	3.05	72	6.78	3.42	0.71	131.6	71.6	1.84	11.72	21	40
16	Manoj Kumar	19/M	115	85	64.27	97	102	0.95	3.54	3.54	100	7.86	2.40	1.44	127.0	82.9	1.35	10.85	43	18
17	Hiruthik	18/M	180	90	27.78	93	110	0.85	4.71	3.54	75	5.66	2.77	1.50	110.0	61.3	1.80	11.74	48	27
18	Neelakandan	18/M	173	86	28.73	101	100	1.01	3.37	3.28	95	6.65	2.83	0.51	92.5	27.5	3.37	8.71	16	18
19	Pragadesh Raj	18/M	182	85	25.66	97	102	0.95	3.90	3.05	78	10.59	4.00	0.62	177.0	58.6	3.02	11.26	58	37
20	Rubesh .Pv	19/M	168	73	25.86	96	110	0.87	5.00	3.88	77	9.01	2.87	0.42	141.1	82.3	1.70	11.55	40	61
21	Rohit	18/M	161	73	28.16	91	94	0.97	4.45	4.37	98	8.84	3.66	1.25	164.3	93.7	1.59	8.96	64	43
22	Kisava Kishor	18/M	177	80	25.54	92	112	0.82	4.61	3.68	79	4.41	2.29	1.76	126.5	56.4	2.24	10.63	26	34
23	Sivaharisaran	19/M	174	92	30.39	91	94	0.97	3.20	3.21	99	7.27	3.80	1.15	141.0	80.3	1.76	11.21	23	15
24	Ragavendra	19/M	184	89	26.29	102	117	0.87	2.32	2.05	88	5.20	0.97	0.32	75.3	121.4	0.62	5.92	45	54
25	Madhan Kumar	18/M	182	85	25.66	97	102	0.95	3.45	3.24	94	8.40	3.07	2.12	149.0	111.9	1.33	12.33	41	47
26	Hariprasad	19/M	168	75	26.57	97	100	0.97	3.56	3.13	87	9.47	3.45	0.70	119.6	47.2	2.53	7.63	96	66
27	Sudhiram	18/M	180	88	27.16	92	112	0.82	2.82	2.28	80	4.94	2.22	0.47	86.0	72.2	1.19	11.64	38	47
28	Jibin	18/M	177	90	28.73	97	100	0.97	4.38	2.95	67	3.83	4.54	3.23	135.7	151.8	0.89	2.37	52	47
29	Elanthamilan	19/M	174	82	27.08	98	107	0.92	5.39	4.49	99	8.20	0.77	0.80	82.4	94.7	0.89	10.77	49	30
30	Gowshik	18/M	183	87	25.98	99	120	0.83	3.85	3.81	99	9.60	1.90	1.32	82.5	85.8	0.99	11.89	45	45
31	Praveen Kumar	18/M	171	90	30.78	99	100	0.99	2.95	2.84	96	6.87	2.77	1.63	110.6	71.8	1.54	11.69	46	48
32	Good Roshan	19/M	170.5	90	30.96	93	113	0.82	2.82	2.28	80	4.94	2.22	0.47	86.0	72.2	1.19	11.64	28	14
33	Dinesh Raj	19/M	171.5	77	26.18	97	102	0.95	2.32	2.05	88	5.20	0.97	0.32	75.3	121.4	0.62	5.92	30	48
34	M. Subramaniyan	18/M	168.7	94	33.03	109	120	0.91	4.38	2.95	67	6.87	5.54	1.32	144.0	151.8	0.80	2.39	46	35
35	Mohan Ansar	19/M	177	86	27.45	92	112	0.82	3.85	3.81	99	9.80	1.09	1.46	92.0	95.8	0.89	10.77	28	17
36	Ilavarasan	19/M	173	75	25.06	91	94	0.97	3.20	3.21	99	7.27	3.80	1.15	141.0	80.3	1.76	11.21	23	15
37	Sivasuryakumar	18/M	169	74	25.91	91	94	0.97	2.84	2.84	99	9.90	2.40	1.54	126.5	55.9	1.85	10.73	25	26